

**APPENDIX I**

**STATISTICAL AND GEOCHEMICAL EVALUATIONS  
OF SITE METALS DATA**

**STATISTICAL  
(TIERS 1 and 2)**

# **Statistical Comparison of Site and Background Data Fill Area at Range 30, Parcel 231(7) Fort McClellan, Alabama**

## **1.0 Introduction**

This report provides the Tier 1 and Tier 2 (Shaw E&I, 2003) site-to-background comparison results for the Fill Area at Range 30, Parcel 231(7), at Fort McClellan in Calhoun County, Alabama. In the first step of the comparison, the maximum detected concentration (MDC) of each element is compared to two times the arithmetic mean of the background data (SAIC, 1998). Any metal that has an MDC greater than the background screening value is carried forward for Tier 2 evaluation, which includes the Slippage Test and the Wilcoxon Rank Sum Test (WRS). If either or both of these statistical test cannot be done, the evaluation will include the Hot Measurement Test.

The methodology and results of the Tier 1 and Tier 2 comparisons are summarized in Tables 1 through 5 and described in more detail in the following sections. Site samples used in the site-to-background comparison include 14 surface soil samples (0 to 1 foot below ground surface [bgs]), 11 subsurface soil (4 to 12 feet bgs), 4 groundwater samples, 1 sediment samples, and 2 surface water samples that were collected at the site.

Background distributions and screening values have been established for target analyte list metals in surface soil, subsurface soil, groundwater, sediment, and surface water for Fort McClellan (SAIC, 1998).

## **2.0 Comparison Methodology**

This section describes the statistical techniques that were employed in the Fill Area at Range 30, Parcel 231(7) site-to-background comparison.

### **2.1 Statistical Procedures**

Contamination can be caused by a variety of processes that yield different spatial distributions of elevated contaminant concentrations. Slight but pervasive contamination can occur from non-point-source releases and can result in slight increases in contaminant concentrations in a large percentage of samples. Localized, or "hot-spot," contamination can result in elevated concentrations in a small percentage of the total number of site samples. No single two-sample statistical comparison test is sensitive to both of these modes of contamination. For this reason,

Table 1

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Surface Soil  
Fill Area at Range 30, Parcel 231(7)  
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation <sup>a</sup>	Tier 2 Evaluation			Carried Forward for Tier 3 Geochemical Evaluation
			Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Hot Measurement Test <sup>b,c</sup>	
Aluminum	14 / 14	Passed	NA	NA	NA	
Antimony	2 / 14	Passed	NA	NA	NA	
Arsenic	14 / 14	Failed	Passed	Passed	NA	
Barium	14 / 14	Passed	NA	NA	NA	
Beryllium	11 / 14	Failed	Passed	Passed	NA	
Cadmium	2 / 14	Passed	NA	NA	NA	
Calcium	14 / 14	Failed	Passed	Passed	NA	
Chromium	14 / 14	Passed	NA	NA	NA	
Cobalt	14 / 14	Passed	NA	NA	NA	
Copper	14 / 14	Failed	Passed	Failed	NA	Yes
Iron	14 / 14	Failed	Passed	Passed	NA	
Lead	14 / 14	Failed	Passed	Failed	NA	Yes
Magnesium	14 / 14	Failed	Passed	Passed	NA	
Manganese	14 / 14	Passed	NA	NA	NA	
Mercury	12 / 14	Failed	Passed	NA <sup>d</sup>	Failed	Yes
Nickel	13 / 14	Failed	Passed	Passed	NA	
Potassium	11 / 14	Passed	NA	NA	NA	
Selenium	12 / 14	Failed	Passed	NA <sup>d</sup>	Failed	Yes
Silver	0 / 14	NA	NA	NA	NA	
Sodium	0 / 14	NA	NA	NA	NA	
Thallium	0 / 14	NA	NA	NA	NA	
Vanadium	14 / 14	Failed	Passed	Passed	NA	
Zinc	14 / 14	Failed	Passed	Passed	NA	

NA = not applicable

a Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or Wilcoxon Rank Sum (WRS) test cannot be performed.

d WRS test is not performed on data sets containing 50% or more nondetects.

Table 2

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Subsurface Soil  
Fill Area at Range 30, Parcel 231(7)  
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation <sup>a</sup>	Tier 2 Evaluation			Carried Forward for Tier 3 Geochemical Evaluation
			Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Hot Measurement Test <sup>b,c</sup>	
Aluminum	11 / 11	Passed	NA	NA	NA	
Antimony	2 / 11	Passed	NA	NA	NA	
Arsenic	11 / 11	Passed	NA	NA	NA	
Barium	11 / 11	Passed	NA	NA	NA	
Beryllium	6 / 11	Passed	NA	NA	NA	
Cadmium	2 / 11	Passed	NA	NA	NA	
Calcium	8 / 11	Passed	NA	NA	NA	
Chromium	11 / 11	Passed	NA	NA	NA	
Cobalt	11 / 11	Passed	NA	NA	NA	
Copper	11 / 11	Passed	NA	NA	NA	
Iron	11 / 11	Passed	NA	NA	NA	
Lead	11 / 11	Passed	NA	NA	NA	
Magnesium	11 / 11	Passed	NA	NA	NA	
Manganese	11 / 11	Passed	NA	NA	NA	
Mercury	11 / 11	Failed	Passed	NA <sup>e</sup>	Failed	Yes
Nickel	10 / 11	Passed	NA	NA	NA	
Potassium	9 / 11	Passed	NA	NA	NA	
Selenium	10 / 11	Failed	NA <sup>d</sup>	NA <sup>e</sup>	Failed	Yes
Silver	0 / 11	NA	NA	NA	NA	
Sodium	0 / 11	NA	NA	NA	NA	
Thallium	0 / 11	NA	NA	NA	NA	
Vanadium	11 / 11	Passed	NA	NA	NA	
Zinc	11 / 11	Passed	NA	NA	NA	

NA = not applicable

a Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or Wilcoxon Rank Sum (WRS) test cannot be performed.

d Slippage test is not performed on data sets for which the maximum background value is a nondetect.

e WRS test is not performed on data sets containing 50% or more nondetects.

Table 3

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Groundwater  
Fill Area at Range 30, Parcel 231(7)  
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation <sup>a</sup>	Tier 2 Evaluation			Carried Forward for Tier 3 Geochemical Evaluation
			Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Hot Measurement Test <sup>b,c</sup>	
Aluminum	2 / 4	Failed	Passed	NA <sup>e</sup>	Failed	Yes
Antimony	0 / 4	NA	NA	NA	NA	
Arsenic	1 / 4	Failed	Passed	NA <sup>e</sup>	Passed	
Barium	4 / 4	Passed	NA	NA	NA	
Beryllium	1 / 4	Failed	NA <sup>d</sup>	NA <sup>e</sup>	Passed	
Cadmium	0 / 4	NA	NA	NA	NA	
Calcium	2 / 4	Passed	NA	NA	NA	
Chromium	1 / 4	Failed	NA <sup>d</sup>	NA <sup>e</sup>	Failed	Yes
Cobalt	1 / 4	Failed	Passed	NA <sup>e</sup>	Failed	Yes
Copper	1 / 4	Failed	Passed	NA <sup>e</sup>	Passed	
Iron	2 / 4	Failed	Passed	NA <sup>e</sup>	Failed	Yes
Lead	1 / 4	Failed	NA <sup>d</sup>	NA <sup>e</sup>	Failed	Yes
Magnesium	2 / 4	Passed	NA	NA	NA	
Manganese	4 / 4	Failed	Passed	NA <sup>e</sup>	Passed	
Mercury	0 / 4	NA	NA	NA	NA	
Nickel	1 / 4	Failed	NA <sup>d</sup>	NA <sup>e</sup>	Failed	Yes
Potassium	1 / 4	Passed	NA	NA	NA	
Selenium	0 / 4	NA	NA	NA	NA	
Silver	0 / 4	NA	NA	NA	NA	
Sodium	0 / 4	NA	NA	NA	NA	
Thallium	0 / 4	NA	NA	NA	NA	
Vanadium	1 / 4	Failed	NA <sup>d</sup>	NA <sup>e</sup>	Failed	Yes
Zinc	1 / 4	Passed	NA	NA	NA	

NA = not applicable

a Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or Wilcoxon Rank Sum (WRS) test cannot be performed.

d Slippage test is not performed on data sets for which the maximum background value is a nondetect.

e WRS test is not performed on data sets with sample sizes less than 5.

Table 4

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Sediment  
Fill Area at Range 30, Parcel 231(7)  
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation <sup>a</sup>	Tier 2 Evaluation			Carried Forward for Tier 3 Geochemical Evaluation
			Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Hot Measurement Test <sup>b,c</sup>	
Aluminum	1 / 1	Passed	NA	NA	NA	
Antimony	0 / 1	NA	NA	NA	NA	
Arsenic	1 / 1	Passed	NA	NA	NA	
Barium	1 / 1	Passed	NA	NA	NA	
Beryllium	1 / 1	Passed	NA	NA	NA	
Cadmium	0 / 1	NA	NA	NA	NA	
Calcium	0 / 1	NA	NA	NA	NA	
Chromium	1 / 1	Passed	NA	NA	NA	
Cobalt	1 / 1	Passed	NA	NA	NA	
Copper	1 / 1	Passed	NA	NA	NA	
Iron	1 / 1	Passed	NA	NA	NA	
Lead	1 / 1	Passed	NA	NA	NA	
Magnesium	1 / 1	Passed	NA	NA	NA	
Manganese	1 / 1	Passed	NA	NA	NA	
Mercury	0 / 1	NA	NA	NA	NA	
Nickel	0 / 1	NA	NA	NA	NA	
Potassium	0 / 1	NA	NA	NA	NA	
Selenium	1 / 1	Passed	NA	NA	NA	
Silver	0 / 1	NA	NA	NA	NA	
Sodium	0 / 1	NA	NA	NA	NA	
Thallium	0 / 1	NA	NA	NA	NA	
Vanadium	1 / 1	Passed	NA	NA	NA	
Zinc	1 / 1	Passed	NA	NA	NA	

NA = not applicable

<sup>a</sup> Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

<sup>b</sup> Part of Tier 2 evaluation per the above referenced memo.

<sup>c</sup> Performed only when the Slippage test and/or Wilcoxon Rank Sum (WRS) test cannot be performed.

Table 5

**Summary of Tier 1 and Tier 2 Site to Background Comparison for Surface Water  
Fill Area at Range 30, Parcel 231(7)  
Fort McClellan, Calhoun County, Alabama**

Metals	Frequency of Detection	Tier 1 Evaluation <sup>a</sup>	Tier 2 Evaluation			Carried Forward for Tier 3 Geochemical Evaluation
			Slippage Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Hot Measurement Test <sup>b,c</sup>	
Aluminum	2 / 2	Passed	NA	NA	NA	
Antimony	0 / 2	NA	NA	NA	NA	
Arsenic	0 / 2	NA	NA	NA	NA	
Barium	2 / 2	Failed	Passed	NA <sup>d</sup>	Passed	
Beryllium	0 / 2	NA	NA	NA	NA	
Cadmium	0 / 2	NA	NA	NA	NA	
Calcium	2 / 2	Failed	Passed	NA <sup>d</sup>	Failed	Yes
Chromium	0 / 2	NA	NA	NA	NA	
Cobalt	0 / 2	NA	NA	NA	NA	
Copper	0 / 2	NA	NA	NA	NA	
Iron	2 / 2	Passed	NA	NA	NA	
Lead	1 / 2	Passed	NA	NA	NA	
Magnesium	2 / 2	Failed	Passed	NA <sup>d</sup>	Passed	
Manganese	2 / 2	Passed	NA	NA	NA	
Mercury	0 / 2	NA	NA	NA	NA	
Nickel	0 / 2	NA	NA	NA	NA	
Potassium	1 / 2	Passed	NA	NA	NA	
Selenium	0 / 2	NA	NA	NA	NA	
Silver	0 / 2	NA	NA	NA	NA	
Sodium	0 / 2	NA	NA	NA	NA	
Thallium	0 / 2	NA	NA	NA	NA	
Vanadium	0 / 2	NA	NA	NA	NA	
Zinc	0 / 2	NA	NA	NA	NA	

NA = not applicable

a Tier 1 evaluation per **Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2**, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or WRS test cannot be performed.

d WRS test is not performed on data sets with sample sizes less than 5.



the use of several simultaneous tests is recommended for a valid and complete comparison of site versus background distributions (U.S. Environmental Protection Agency [EPA], 1989, 1992, and 1994; U.S. Navy, 2002).

Analytes that fail the Tier 1 and Tier 2 comparisons are subject to a geochemical evaluation to determine if the elevated concentrations are due to natural processes or if they represent potential contamination.

### **2.1.1 Tier 1**

In this step of the background screening process, MDC of the site data set is compared to the background screening value of two times the background mean (SAIC, 1998). Elements for which the site MDC does not exceed the background screening value are considered to be present at background concentrations and are not considered site-related chemicals. Elements for which the site MDC exceeds the background screening value undergo further evaluation (Tier 2).

### **2.1.2 Tier 2**

**Slippage Test.** The nonparametric Slippage test is designed to detect a difference between the upper tails of two distributions, and has been recommended for use in site-to-background comparisons to identify potential localized, or hot-spot, contamination (U.S. Navy, 2002). The test is performed by counting the number ( $K$ ) of detected concentrations in the site data set that exceed the maximum background measurement, and then comparing this number to a critical value ( $K_c$ ), which is a function of the number of background samples and the number of site samples. If  $K > K_c$ , then potential contamination is indicated and the analyte will be subjected to geochemical evaluation. If  $K \leq K_c$ , then localized contamination is not suspected.

Critical values tables for site and background data sets up to size  $n = 50$  are provided in U.S. Navy (2002). Critical values for larger data sets are calculated using the test statistic provided in Rosenbaum (1954). In this report, the Slippage test is performed at the 95 percent confidence level. The test cannot be performed if the maximum background value is a nondetect because the actual concentration in that sample is unknown.

**Wilcoxon Rank Sum Test.** The nonparametric WRS test is designed to detect a difference between the medians of two data sets and has been recommended for use in site-to-background comparisons to identify slight but pervasive contamination (EPA, 2000; U.S. Navy, 2002). In this report, the WRS test is performed when the site and background data sets each contain less

than 50 percent nondetects (i.e., measurements reported as not detected below the laboratory reporting limit). The WRS test will not be performed on data sets containing 50 percent or more nondetects. The medians of such data sets are unknown, and hence the test results would lack sufficient power to yield reliable results.

The WRS test compares two data sets of size  $n$  and  $m$  ( $n > m$ ) and tests the null hypothesis that the samples were drawn from populations with distributions having the same medians. To perform the test, the two sets of observations are pooled and arranged in order from smallest to largest. Each observation is assigned a rank; that is, the smallest is ranked 1, the next largest is ranked 2, and so on up to the largest observation, which is ranked  $(n + m)$ . If ties occur between or within samples, each one is assigned the mid-rank. Next, the sum of the ranks of smaller data set  $m$  is calculated. Then the test statistic  $Z$  is determined,

$$Z = \frac{W - m(m + n + 1)/2}{\sqrt{mn(m + n + 1)/12}}$$

Where:

- $W$  = Sum of the ranks of the smaller data set
- $m$  = Number of data points in smaller group
- $n$  = Number of data points in larger group.

This test statistic  $Z$  is used to find the two-sided significance. For instance, if the test statistic yields a probability of a Type I error (p-level) less than 0.2, then there is a statistically significant difference between the medians at the 80 percent confidence level. A Type I error involves rejecting the null hypothesis when it is true. If the p-level is greater than 0.2, then there is no reasonable justification to reject the null hypothesis at the 80 percent confidence level. It can, therefore, be concluded that the medians of the two data sets are similar, and it can be assumed to be drawn from the same population.

If the p-level is less than 0.2, then the medians of the two distributions are significantly different at the 80 percent confidence level. This can occur if the site data are shifted higher or lower than the background data. If the site data are shifted higher relative to background, then contamination may be indicated, and the analyte in question will be carried on for geochemical evaluation; however, if the site data are shifted lower relative to background, then contamination is not indicated. If the p-level is greater than 0.2, then pervasive site contamination is not suspected.

**Box Plots.** A quick, robust graphical method recommended by the EPA to visualize and compare two or more groups of data is the box plot comparison (EPA, 1989 and 1992). These plots provide a summary view of the entire data set, including the overall location and degree of symmetry. The box encloses the central 50 percent of the data points so that the top of the box represents the 75<sup>th</sup> percentile and the bottom of the box represents the 25<sup>th</sup> percentile. The small box within the larger box represents the median of the data set. The upper whisker extends outward from the box to the maximum point and the lower whisker extends to the minimum point. Nondetect results are set equal to one-half of the reporting limit for plotting purposes.

For each analyte, box plots of site and background data are placed side by side to visually compare the distributions and qualitatively determine whether the data sets are similar or distinct. Accordingly, the box plots are a necessary adjunct to the WRS test. As described previously, the WRS test may indicate that the medians of the site and background data sets are significantly different. Examination of the box plots will confirm whether that difference is caused by site data that are shifted higher or lower relative to background.

**Hot Measurement Test.** The hot measurement test consists of comparing each site measurement with a concentration value that is representative of the upper limit of the background distribution (EPA, 1994). Ideally, a site sample with a concentration above the background screening value would have a low probability of being a member of the background distribution and may be an indicator of contamination. It is important to select such a background screening value carefully so that the probability of falsely identifying site samples as contaminated or uncontaminated is minimized.

The 95<sup>th</sup> upper tolerance limit (95<sup>th</sup> UTL) is recommended as a screening value for normally or lognormally distributed analytes and the 95<sup>th</sup> percentile is recommended as a screening value for nonparametrically distributed analytes (EPA, 1989, 1992, and 1994). Site samples with concentrations above these values are not necessarily contaminated, but should be considered suspect. To perform the test, each analyte's site MDC is compared to the background 95<sup>th</sup> UTL, or 95<sup>th</sup> percentile, in accordance with the type of background distribution. If the site MDC exceeds the background screening value, then that analyte will undergo a geochemical evaluation. If the MDC does not exceed the background threshold value, then hot-spot contamination is not indicated.

### **2.1.3 Geochemical Evaluation**

If an analyte fails either of the statistical tests described above, then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The methodology and results of the geochemical evaluation are provided in Appendix H.

## **3.0 Results of the Site-to-Background Comparisons**

This section presents the results of the site-to-background comparisons for 23 TAL metals in the Fill Area at Range 30, Parcel 231(7), soil, groundwater, sediment, and surface water samples. Tables 1 through 5 summarize the Tier 1 and Tier 2 test results for each media as discussed in the following sections. Statistical test results are discussed in detail below. Box plots are also discussed below and are provided in Attachment 1.

### **3.1 Surface Soil**

Twenty-three TAL metals were evaluated in the Parcel 231 surface soil. Three metals (silver, sodium, and thallium) had no detected concentrations in surface soil, so no further discussion of these metals is included.

Eight metals (aluminum, antimony, barium, cadmium, chromium, cobalt, manganese, and potassium) had no detected concentrations above the background screening value, passing the Tier 1 evaluation. These metals will not be tested or discussed any further.

The remaining 12 metals underwent Tier 2 evaluation. The statistical test results and box plots are discussed in detail below.

Table 1 summarizes the Tier 1 and Tier 2 test results for surface soil.

#### **Arsenic**

##### Tier 1 Evaluation

One site sample exceeds the background screening value of 13.73 milligrams per kilogram (mg/kg).

##### Tier 2 Evaluation

##### Slippage Test

The critical value,  $K_c$ , for arsenic is 2. No site samples exceed the maximum background measurement ( $K=0$ ). Because  $K < K_c$ , arsenic passes the Slippage test.

##### WRS Test

The WRS test p-level of 0.2847 indicates a good agreement between the site and background distributions.

### Box Plot

Box plots for the site and background data sets are provided in Figure 1-1. The site median is slightly higher than that of background. The site 75<sup>th</sup> percentile and maximum are lower than the corresponding background values. The site minimum and 25<sup>th</sup> percentile are higher than the corresponding background values.

### Conclusion

Arsenic in surface soil is considered to be within the range of background.

## **Beryllium**

### Tier 1 Evaluation

Two site samples exceed the background screening value of 0.8 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for beryllium is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , beryllium passes the Slippage test.

### WRS Test

The p-level of 0.229 indicates a good agreement between the site and background distributions.

### Box Plot

The site and background medians are similar (Figure 1-1). The site minimum and 25<sup>th</sup> percentile are higher than the corresponding background values. The site 75<sup>th</sup> percentile and maximum are slightly lower compared to background.

### Conclusion

Beryllium in surface soil is considered to be within the range of background.

## **Calcium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 1,723 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for calcium is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , calcium passes the Slippage test.

### WRS Test

The p-level of 0.272 indicates a good agreement between the site and background distributions.

### Box Plot

The site minimum, 25<sup>th</sup> percentile, and median are higher than the corresponding background values (Figure 1-2). The site and background 75<sup>th</sup> percentiles are similar, and the site maximum is less than that of background.

### Conclusion

Calcium in surface soil is considered to be within the range of background.

## **Copper**

### Tier 1 Evaluation

Five site samples exceed the background screening value of 12.71 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for copper is 2, and 1 site sample exceeds the maximum background measurement. Because  $K < K_c$ , copper passes the Slippage test.

#### WRS Test

The p-level of 0.039 indicates a significant difference between the site and background distributions.

#### Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-2).

### Conclusion

Because copper in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Iron**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 34,154 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for iron is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , iron passes the Slippage test.

#### WRS Test

The p-level of 0.47 indicates a good agreement between the site and background distributions.

#### Box Plot

The site minimum, 25<sup>th</sup> percentile, and median are elevated compared to the corresponding background values (Figure 1-3). The site 75<sup>th</sup> percentile and maximum are less than that of background.

### Conclusion

Iron in surface soil passed the Tier 2 Evaluation and is considered to be within the range of background.

## **Lead**

### Tier 1 Evaluation

Three site samples exceed the background screening value of 40.05 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for lead is 2, and 2 site samples exceed the maximum background measurement. Because  $K \leq K_c$ , lead passes the Slippage test.

#### WRS Test

The p-level of 0.11 indicates a weak agreement between the site and background distributions.

#### Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-3).

#### Conclusion

Because lead in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Magnesium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 1,033 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for magnesium is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , magnesium passes the Slippage test.

#### WRS Test

The p-level of 0.2636 indicates a good agreement between the site and background distributions.

#### Box Plot

The site median is slightly higher than that of background (Figure 1-4). The site minimum, 25<sup>th</sup> percentile, and 75<sup>th</sup> percentile are higher than the corresponding background values. The site maximum is lower compared to background.

#### Conclusion

Magnesium in surface soil passed the Tier 2 evaluation and is considered to be within the range of background.

## **Mercury**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.08 mg/kg.

## Tier 2 Evaluation

### Slippage Test

$K_c$  for mercury is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , mercury passes the Slippage test.

### WRS Test

The WRS test was not performed because the background data set contains more than 50 percent nondetects.

### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-4). The site maximum is lower than that of background. The shape and location of the background box plot are influenced by the percentage of nondetects (66 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.125 mg/kg.

### Conclusion

Because mercury in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Nickel**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 10.33 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for nickel is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , nickel passes the Slippage test.

#### WRS Test

The p-level of 0.45 indicates a good agreement between the site and background distributions.

#### Box Plot

The site and background medians are the same (Figure 1-5). The site minimum and 25<sup>th</sup> percentile are higher than the corresponding background values, and the site maximum and 75<sup>th</sup> percentile are lower than those of background.

#### Conclusion

Nickel in surface soil is considered to be within the range of background.

## **Selenium**

### Tier 1 Evaluation

Ten site samples exceed the background screening value of 0.48 mg/kg.



## Tier 2 Evaluation

### Slippage Test

$K_c$  for selenium is 2, and one site sample exceeds the maximum background measurement. Because  $K < K_c$ , selenium passes the Slippage test.

### WRS Test

No WRS test was performed because the background data set contains more than 50 percent nondetects.

### Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-5). The shape and location of the background box plot are influenced by the high percentage of nondetects (99 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.563 mg/kg.

### Conclusion

Because selenium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Vanadium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 58.84 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for vanadium is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , vanadium passes the Slippage test.

#### WRS Test

The p-level of 0.516 indicates a strong agreement between the background and site distributions.

#### Box Plot

The site and background medians appear to be the same (Figure 1-6). The site minimum and 25<sup>th</sup> percentile are higher than the corresponding background values. The site 75<sup>th</sup> percentile and maximum are lower than those of background.

#### Conclusion

Vanadium in surface soil is considered to be within the range of background.

## **Zinc**

### Tier 1 Evaluation

Two site samples exceed the background screening value of 40.64 mg/kg.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for zinc is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , zinc passes the Slippage test.

#### WRS Test

The p-level of 0.5998 indicates a good agreement between the site and background distributions.

#### Box Plot

The site and background medians are the same (Figure 1-6). The site minimum, 25<sup>th</sup> percentile, and 75<sup>th</sup> percentile are slightly higher compared to the corresponding background values. The site maximum is lower compared to that of background.

#### Conclusion

Zinc in surface soil passed the Tier 2 evaluation and is considered to be within the range of background.

### **3.2 Subsurface Soil**

Twenty-three TAL metals were evaluated in subsurface soil at Parcel 231. Three metals (silver, sodium, and thallium) had no detected concentrations in the site samples. No further discussion of these metals is included.

Eighteen metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, vanadium, and zinc) had no detected concentrations above the background screening value, passing the Tier 1 evaluation. No further testing or discussion of these metals is included.

The remaining 2 metals underwent Tier 2 evaluation. The statistical tests and box plots are discussed in detail below.

Table 2 summarizes the Tier 1 and Tier 2 test results for subsurface soil.

### **Mercury**

#### Tier 1 Evaluation

Two site samples exceed the background screening value of 0.07 mg/kg.

#### Tier 2 Evaluation

##### Slippage Test

The critical value,  $K_c$ , for mercury is 2. One site sample exceeds the maximum background measurement. Because  $K < K_c$ , mercury passes the Slippage test.

#### WRS Test

The WRS test was not performed because the background data set has more than 50 percent nondetects.

#### Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-7). The shape and location of the background box plot are influenced by the percentage of nondetects (53 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.094 mg/kg.

#### Conclusion

Because mercury in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

### **Selenium**

#### Tier 1 Evaluation

Nine site samples exceed the background screening value of 0.47 mg/kg.

#### Tier 2 Evaluation

##### Slippage Test

The maximum result in background is a nondetect, so the Slippage test is not done.

#### WRS Test

The WRS test was not performed because the background data set has more than 50% nondetects.

#### Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-7). The shape and location of the background box plot are influenced by the percentage of nondetects (99 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.574 mg/kg.

#### Conclusion

Because selenium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

### **3.3 Groundwater**

This section presents the results of the site-to-background comparisons for 23 metals in unfiltered groundwater samples.

Seven metals (antimony, cadmium, mercury, selenium, silver, sodium, and thallium) had no detected results in the site samples and are not discussed any further.

Five metals had no detected concentrations exceeding the background screening value, passing the Tier 1 evaluation. These metals (barium, calcium, magnesium, potassium, and zinc) will not be included in any further evaluation or discussion.

The remaining eleven metals underwent Tier 2 evaluation. The results of these statistical tests are discussed in detail below and summarized in Table 3. Box plots are provided in Attachment 1.

Table 3 summarizes the groundwater Tier 1 and Tier 2 test results.

## **Aluminum**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 2.335 mg/L.

### Tier 2 Evaluation

#### Slippage Test

The critical value,  $K_c$ , for aluminum is 2. One site sample exceeds the maximum background measurement ( $K = 1$ ). Because  $K < K_c$ , aluminum passes the Slippage test.

#### WRS Test

The WRS test is not performed because the site data set has less than 5 samples.

#### Box Plot

The site median is lower than that of background (Figure 1-8). The site minimum, 25<sup>th</sup> percentile, 75<sup>th</sup> percentile, and maximum are higher. The shape and location of the site box plot is influenced by the small sample size (less than 5 samples).

#### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 5.95 mg/L.

### Conclusion

Because aluminum in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Arsenic**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.01776 mg/L.

## Tier 2 Evaluation

### Slippage Test

The critical value,  $K_c$ , for arsenic is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , arsenic passes the Slippage test.

### WRS Test

The WRS test is not performed because the background data set has greater than 50 percent nondetects and the site data set has fewer than 5 samples.

### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-8). The site maximum is lower than that of background. The shape and location of the background box plot are influenced by the high percentage of nondetects (84 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

### Hot Measurement Test

The site MDC is lower than the background 95<sup>th</sup> percentile of 0.117 mg/L.

### Conclusion

Arsenic in groundwater is considered to be within the range of background.

## **Beryllium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.001247 mg/L.

### Tier 2 Evaluation

#### Slippage Test

The maximum value for beryllium is a nondetect, so the Slippage test was not performed.

#### WRS Test

The WRS test is not performed because the background data set has greater than 50 percent nondetects and the site data set has fewer than 5 samples.

#### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-9). The site maximum is the same as that of background. The shape and location of the background box plot are influenced by the high percentage of nondetects (72 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC of beryllium is less than the background 95<sup>th</sup> percentile of 0.005 mg/L.

#### Conclusion

Beryllium in groundwater passed the Tier 2 evaluation and is considered to be within the range of background.

## **Chromium**

### Tier 1 Evaluation

There is no background screening value for chromium. One site sample has a detected result.

### Tier 2 Evaluation

#### Slippage Test

The maximum value for chromium is a nondetect, so the Slippage test was not performed.

#### WRS Test

The WRS test is not performed because the background data set has greater than 50 percent nondetects and the site data set has fewer than 5 samples.

#### Box Plot

The site 25<sup>th</sup> percentile and median are the same as the corresponding background values (Figure 1-9). The site minimum, 75<sup>th</sup> percentile, and maximum are higher than the corresponding background values. The shape and location of the background box plot are influenced by the high percentage of nondetects (100 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.0168 mg/L.

### Conclusion

Because chromium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Cobalt**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.02336 mg/L.

### Tier 2 Evaluation

#### Slippage Test

$K_c$  for cobalt is 2, and one site sample exceeds the maximum background measurement. Because  $K < K_c$ , cobalt passes the Slippage test.

#### WRS Test

The WRS test is not performed because the background data set has greater than 50 percent nondetects and the site data set has fewer than 5 samples.

#### Box Plot

The site minimum, interquartile range, and the maximum are higher than the corresponding background values (Figure 1-10). The shape and location of the background box plot are influenced by the high percentage of nondetects (94 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC of cobalt exceeds the background 95<sup>th</sup> percentile of 0.0202 mg/L.

#### Conclusion

Because cobalt in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

### **Copper**

#### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.02548 mg/L.

#### Tier 2 Evaluation

##### Slippage Test

$K_c$  for copper is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , copper passes the Slippage test.

##### WRS Test

The WRS test is not performed because the background data set has greater than 50 percent nondetects and the site data set has fewer than 5 samples.

##### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-10). The site maximum is less than that of background. The shape and location of the background box plot are influenced by the high percentage of nondetects (82 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC of copper is less than the background 95<sup>th</sup> percentile of 0.207 mg/L.

#### Conclusion

Copper passed the Tier 2 evaluation and is considered to be within the range of background.

### **Iron**

#### Tier 1 Evaluation

One site sample exceeds the background screening value of 7.04 mg/L.

##### Slippage Test

$K_c$  for iron is 2, and one site sample exceeds the maximum background measurement. Because  $K < K_c$ , iron passes the Slippage test.

##### WRS Test

The WRS test is not performed because the site data set has fewer than 5 samples.

##### Box Plot

The site 25<sup>th</sup> percentile and median are lower than the corresponding background values (Figure 1-11). The site minimum, 75<sup>th</sup> percentile, and maximum are higher than that of background.

#### Hot Measurement Test

The site MDC of iron exceeds the 95<sup>th</sup> percentile of 22 mg/L.

#### Conclusion

Because iron in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

#### **Lead**

##### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.007998 mg/L.

##### Slippage Test

The maximum value for lead is a nondetect, so the Slippage test was not performed.

##### WRS Test

The WRS test was not performed because the background data set contains 50 percent or more nondetects and the site data set has fewer than 5 samples

##### Box Plot

The site median is slightly lower than that of background (Figure 1-11). The site minimum, 25<sup>th</sup> percentile, 75<sup>th</sup> percentile, and maximum are higher than the corresponding background values. The shape and location of the background box plot are influenced by the percentage of nondetects (60 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC of lead is greater than the background 95<sup>th</sup> percentile of 0.0434 mg/L.

#### Conclusion

Because lead in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

#### **Manganese**

##### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.5805 mg/L.

##### Slippage Test

$K_c$  for manganese is 2, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , manganese passes the Slippage test.

##### WRS Test

The WRS test was not performed because the site data set has fewer than 5 samples.



#### Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-12). The site maximum is less than that of background.

#### Hot Measurement Test

The site MDC is less than the background 95<sup>th</sup> percentile of 4.134 mg/L.

#### Conclusion

Manganese in groundwater is considered to be within the range of background.

### **Nickel**

#### Tier 1 Evaluation

No background screening value is available for nickel. One site sample had a detected result.

#### Slippage Test

The Slippage test was not performed because the maximum value in the background data is a nondetect.

#### WRS Test

The WRS test was not performed because the background data set has 50 percent or more nondetects and the site data contains fewer than 5 samples.

#### Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-12). The shape and location of the background box plot are influenced by the high percentage of nondetects (100 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC exceeds the background 95<sup>th</sup> percentile of 0.0343 mg/L.

#### Conclusion

Because nickel in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

### **Vanadium**

#### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.016975 mg/L.

#### Slippage Test

The Slippage test was not performed because the maximum value in the background data is a nondetect.

#### WRS Test

The WRS test was not performed because the background data set has 50 percent or more nondetects and the site data contains fewer than 5 samples.

#### Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-13). The shape and location of the background box plot are influenced by the high percentage of nondetects (96 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

#### Hot Measurement Test

The site MDC of vanadium exceeds the background 95<sup>th</sup> percentile of 0.0276 mg/L.

#### Conclusion

Because vanadium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

### **3.4 Sediment**

This section presents the results of the site-to-background comparisons for 23 TAL metals for Parcel 231 sediment samples. Nine metals (antimony, cadmium, calcium, mercury, nickel, potassium, silver, sodium, and thallium) had no detected concentrations in sediment. No further discussion of these elements is included.

The remaining 14 metals (aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, iron, lead, magnesium, manganese, selenium, vanadium, and zinc) had no site samples exceeding their respective background screening value. Because these metals passed the Tier 1 evaluation, they will not be tested or discussed any further.

Table 4 summarizes the results for sediment.

### **3.5 Surface Water**

This section presents the results of the site-to-background comparisons for the 23 metals tested in surface water samples from Parcel 231. Fifteen metals (antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, mercury, nickel, selenium, silver, sodium, thallium, vanadium, and zinc) had no detected concentrations in the site samples and are not discussed any further.

Five metals (aluminum, iron, lead, manganese, and potassium) had no detected concentrations exceeding their respective background screening values. These metals are considered within the range of background based on the Tier 1 evaluation, and will not be tested or discussed further.

The remaining three metals (barium, calcium, and magnesium) underwent Tier 2 evaluation. The results of these tests are discussed in detail below.

Table 5 summarizes the Tier 1 and Tier 2 surface water results.

## **Barium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.07536 mg/L.

### Slippage Test

$K_c$  for barium is 1, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , barium passes the Slippage test.

### WRS Test

The WRS test was not performed because the site data contains fewer than 5 samples.

### Box Plot

Box plots were not done because the site data set has just 2 samples.

### Hot Measurement Test

The site MDC of barium is less than the background 95<sup>th</sup> percentile of 0.115 mg/L.

### Conclusion

Barium in surface water passed the Tier 2 evaluation and is considered to be within the range of background.

## **Calcium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 25.166 mg/L.

### Slippage Test

$K_c$  for calcium is 1, and no site samples exceed the maximum background measurement. Because  $K < K_c$ , calcium passes the Slippage test.

### WRS Test

The WRS test was not performed because the site data contains fewer than 5 samples.

### Box Plot

Box plots were not done because the site data set has just 2 samples.

### Hot Measurement Test

The site MDC of calcium exceeds the background 95<sup>th</sup> percentile of 37.8 mg/L.

### Conclusion

Because calcium in surface water failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

## **Magnesium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 10.972 mg/L.

### Slippage Test

$K_c$  for magnesium is 1, and no site samples exceed the maximum background value. Because  $K < K_c$ , magnesium passes the Slippage test.

### WRS Test

The WRS test was not performed because the site data contains fewer than 5 samples.

### Box Plot

Box plots were not done because the site data set has just 2 samples.

### Hot Measurement Test

The site MDC of magnesium is less than the background 95<sup>th</sup> percentile of 50.536 mg/L.

### Conclusion

Magnesium in surface water passed the Tier 2 evaluation and is considered to be within the range of background.

## **4.0 Summary and Conclusions**

The statistical methodology used to compare site data from the Fill Area at Range 30, Parcel 231(7) and the background data sets for 23 elements in surface soil, subsurface soil, groundwater, sediment, and surface water, includes a comparison of the site MDC to the background screening value (Tier 1 evaluation). Analytes that failed this comparison were subjected to the Slippage test and Wilcoxon rank sum test, and box-and-whisker plots were prepared to visually compare the two data sets and properly interpret the WRS test results. If the Slippage test and/or the WRS test could not be performed, the Hot Measurement test was included as part of the Tier 2 statistical evaluation. Analytes that underwent Tier 2 evaluation and failed any component of the statistical site-to-background comparison are carried forward for Tier 3 geochemical evaluation to determine if natural processes can explain the elevated concentrations.

Tables 1 through 5 summarize the comparison test results and the metals carried forward for geochemical evaluation.

## 5.0 References

Rosenbaum, S., 1954, "Tables for a Nonparametric Test of Location," *Annals of Mathematical Statistics*, Vol. 24, pp. 146-150.

Science Application International Corporation (SAIC), 1998, *Final Background Metals Survey Report, Fort McClellan, Anniston, Alabama*, prepared for U.S. Army Corps of Engineers, Mobile, Alabama, July.

Shaw Environmental and Infrastructure (Shaw E&I), 2003, *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2*, Technical Memorandum, 24 June 2003 by Paul Goetchius.

U.S. Environmental Protection Agency (EPA), 1989, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance*, Office of Solid Waste, Waste Management Division, EPA/530/SW-89/026, July.

U.S. Environmental Protection Agency (EPA), 1992, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance*, Environmental Statistics and Information Division, Office of Policy, Planning, and Evaluation, EPA/530/R-93/003, July.

U.S. Environmental Protection Agency (EPA), 1994, *Statistical Methods For Evaluating The Attainment Of Cleanup Standards*, Environmental Statistics and Information Division, Office of Policy, Planning, and Evaluation, EPA/230/R-94/004, June.

U.S. Environmental Protection Agency (EPA), 2000, *Guidance for Data Quality Assessment: Practical Methods for Data Analysis, EPA QA/G-9, QA00 Update*, Office of Environmental Information, EPA/600/R-96/084, July.

U.S. Navy, 2002, *Guidance for Environmental Background Analysis, Volume 1: Soil*, NFESC User's Guide UG-2049-ENV, Naval Facilities Engineering Command, Washington, D.C., April.

## **ATTACHMENT 1**

Figure 1-1

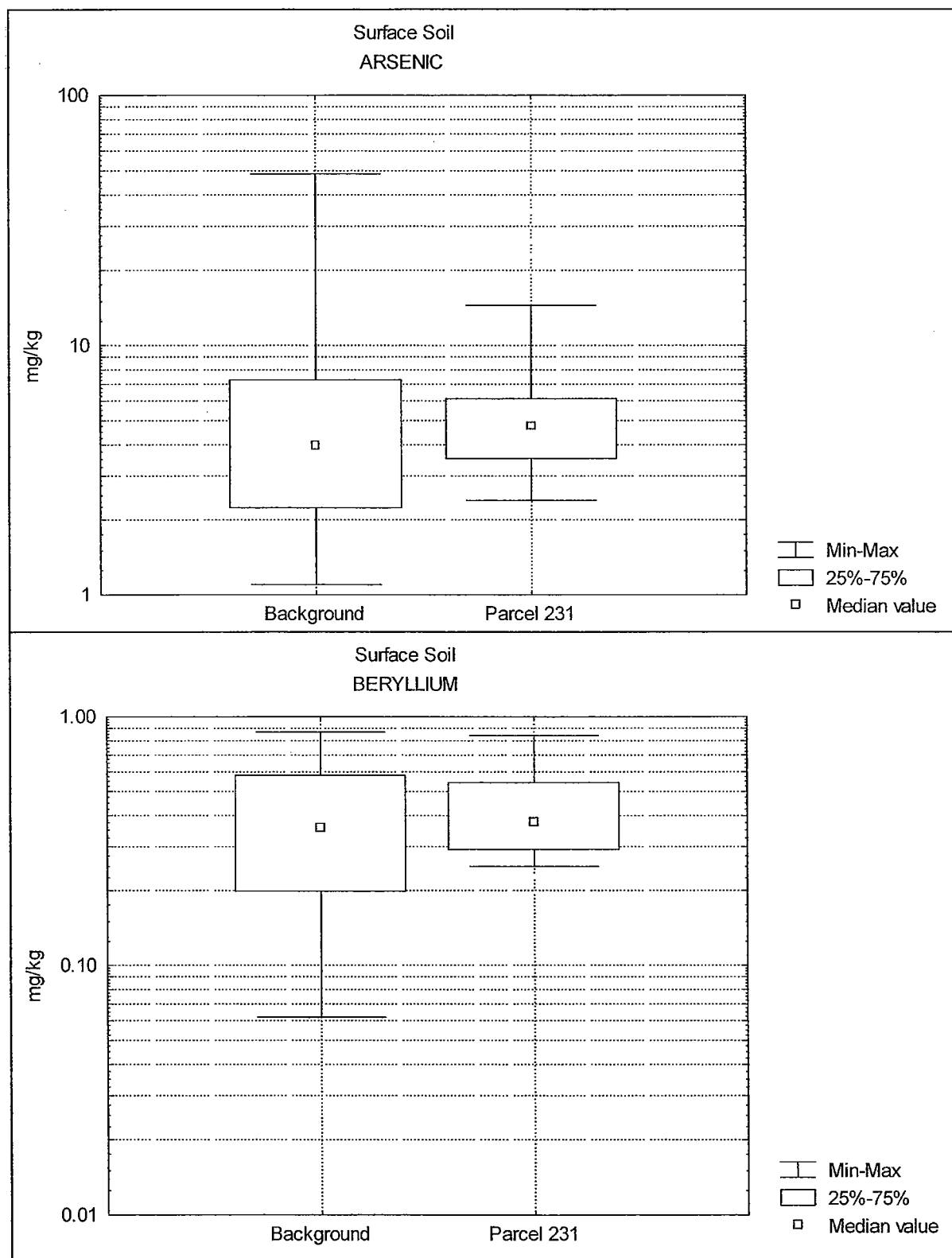


Figure 1-2

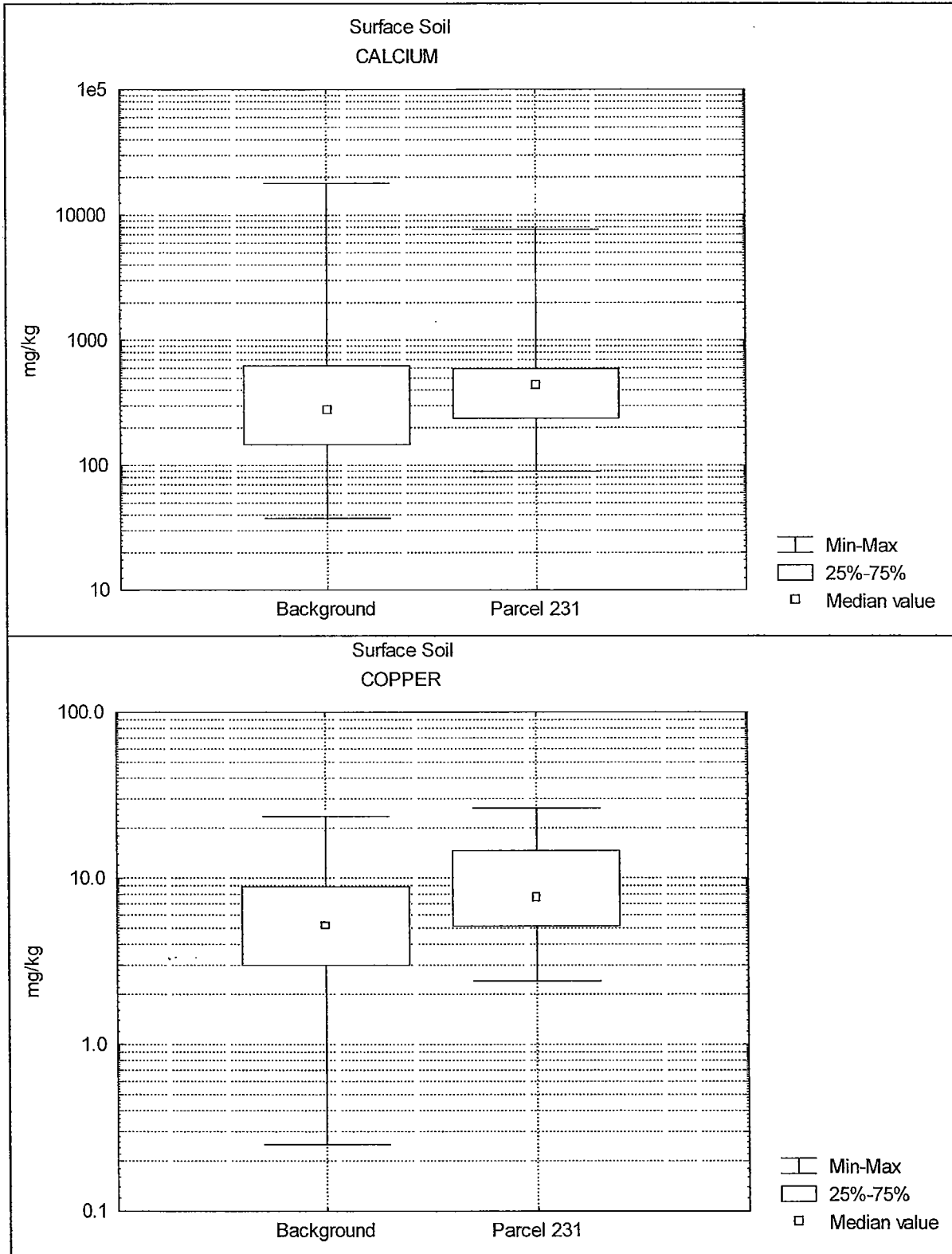




Figure 1-3

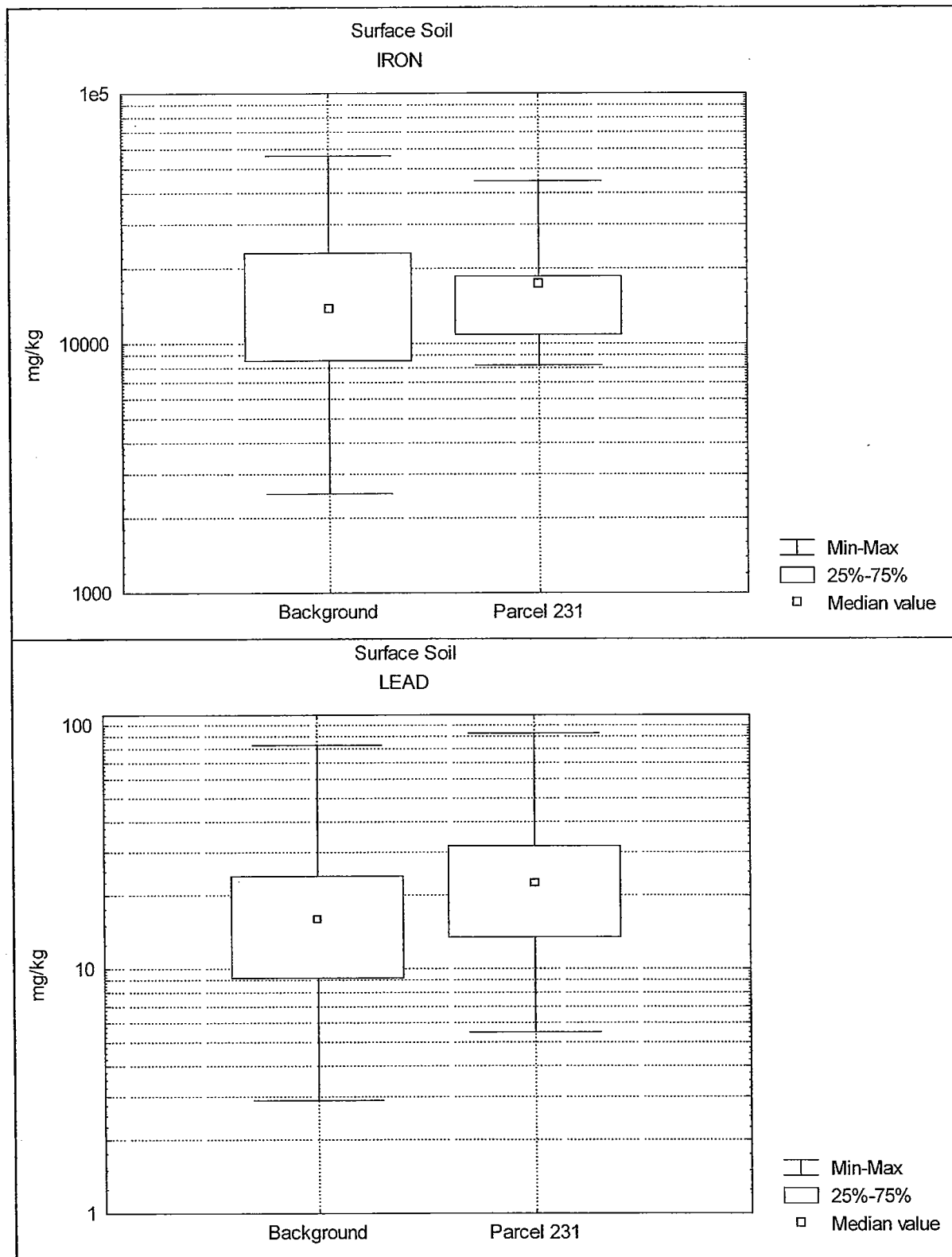


Figure 1-4

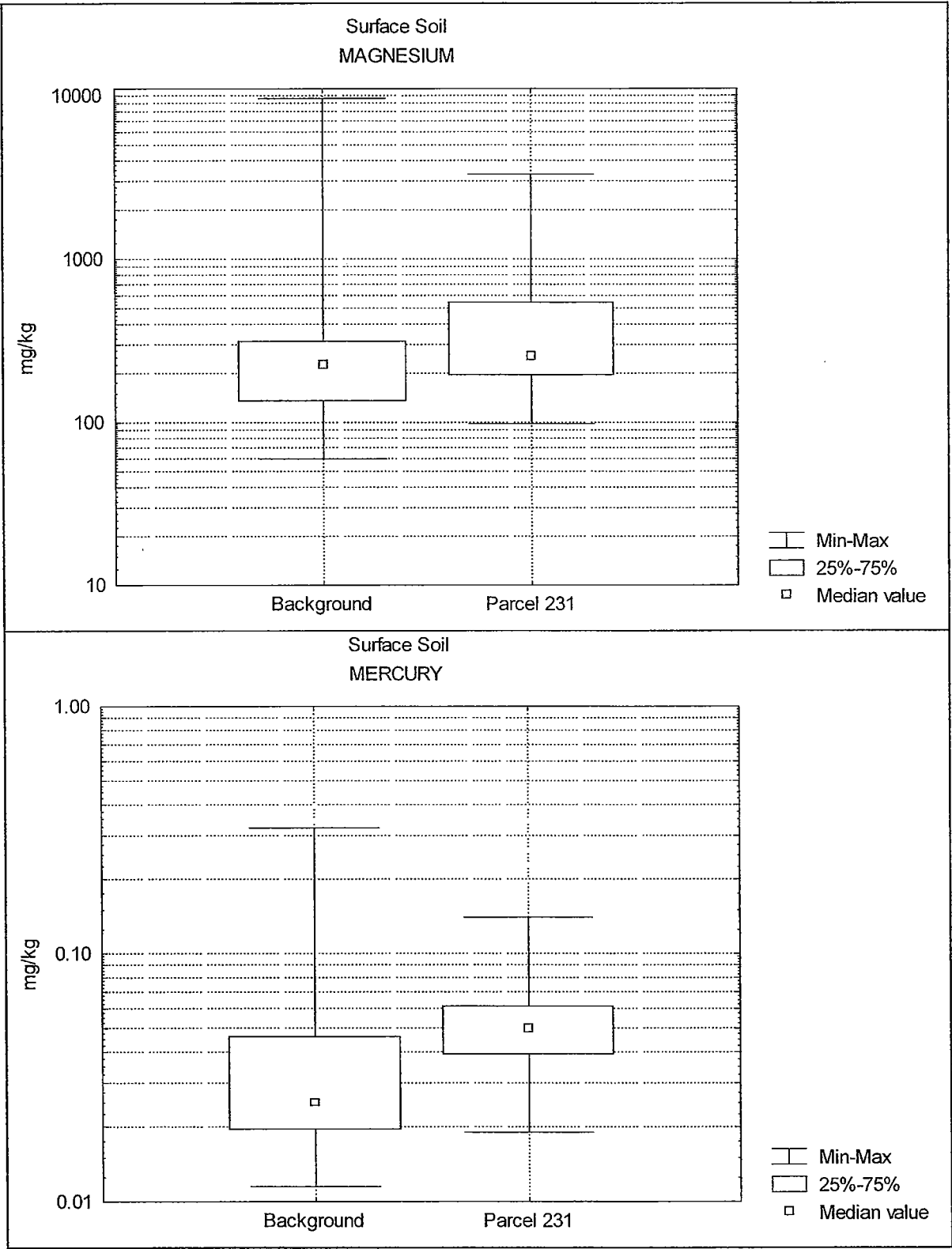


Figure 1-5

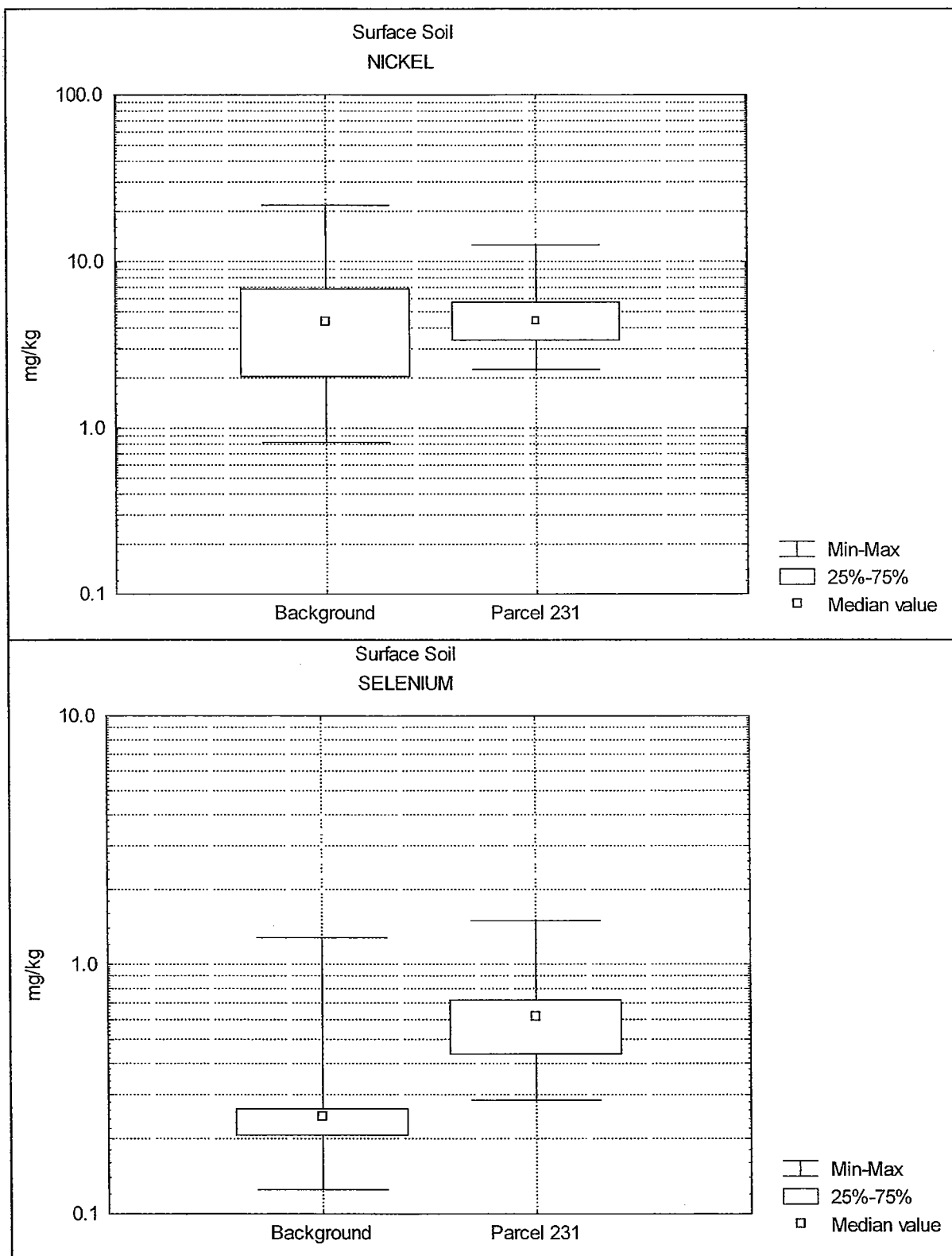


Figure 1-6

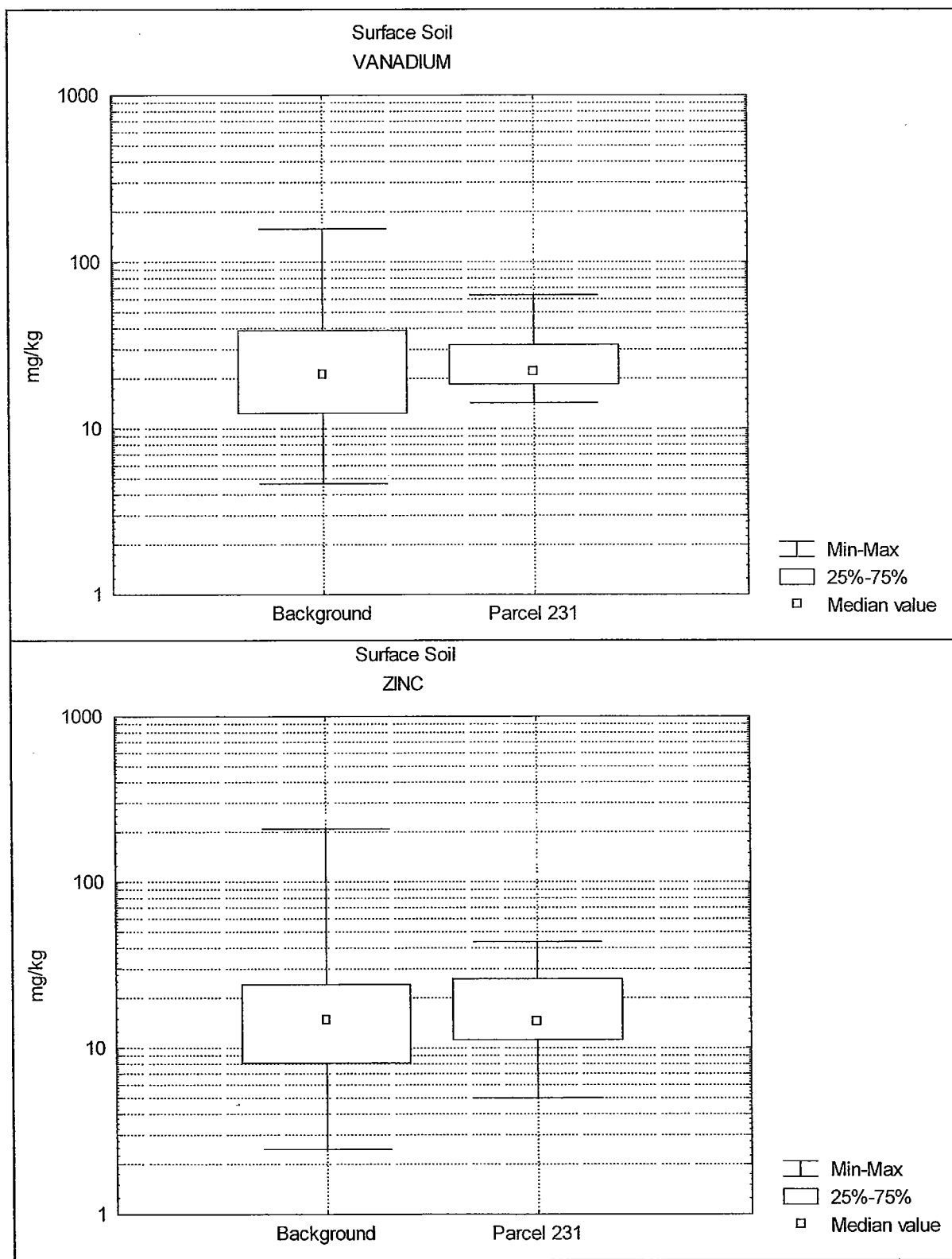


Figure 1-7

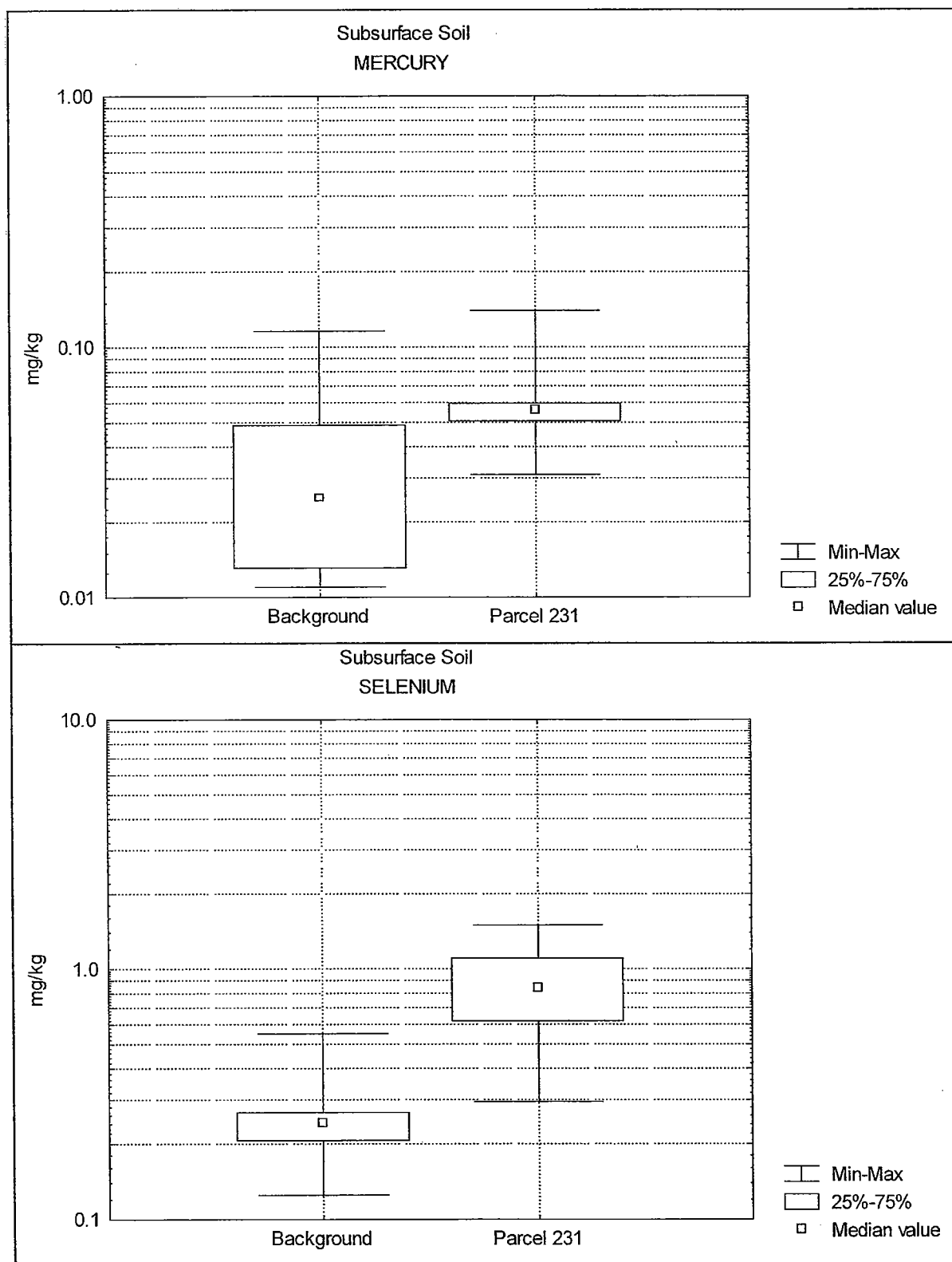


Figure 1-8

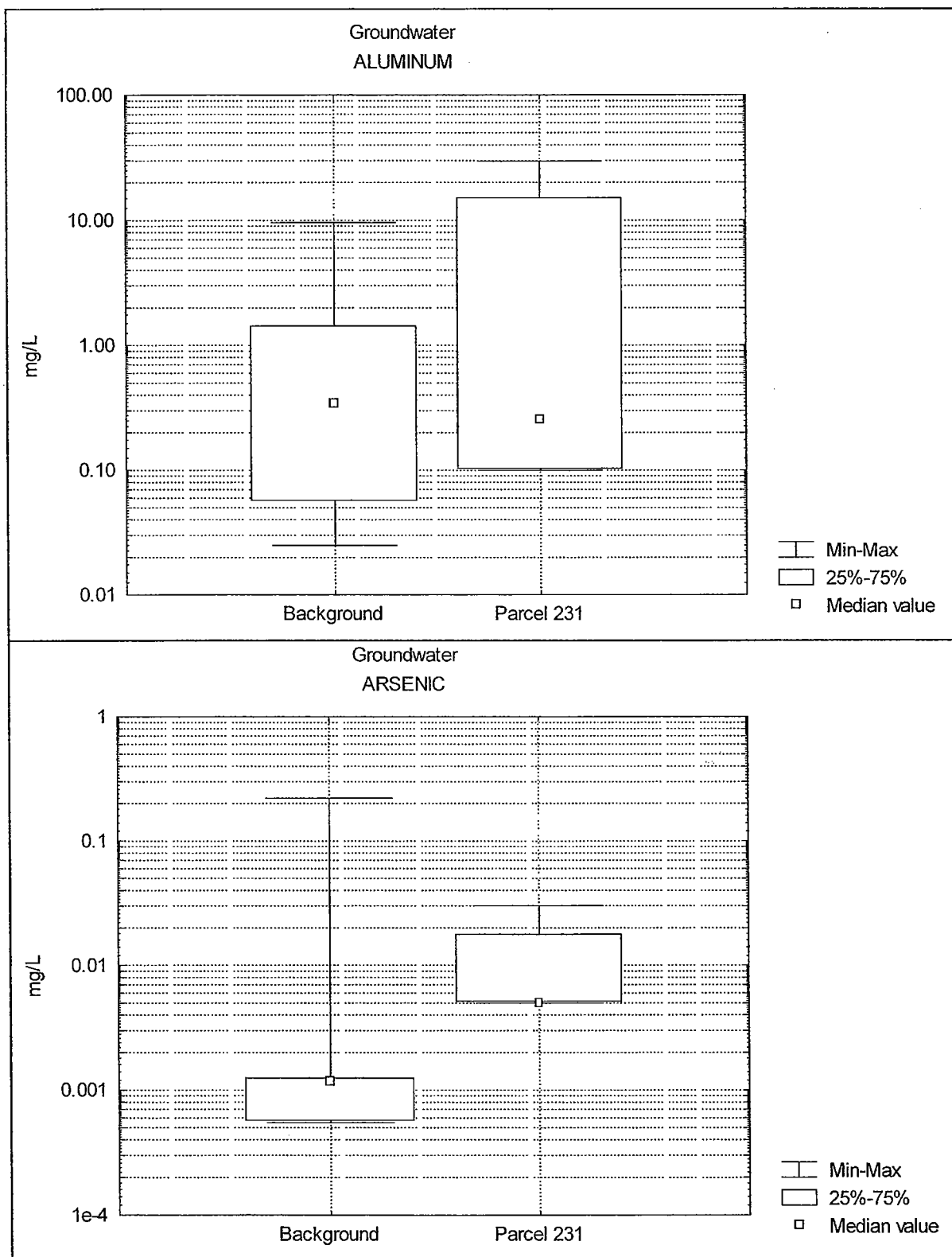


Figure 1-9

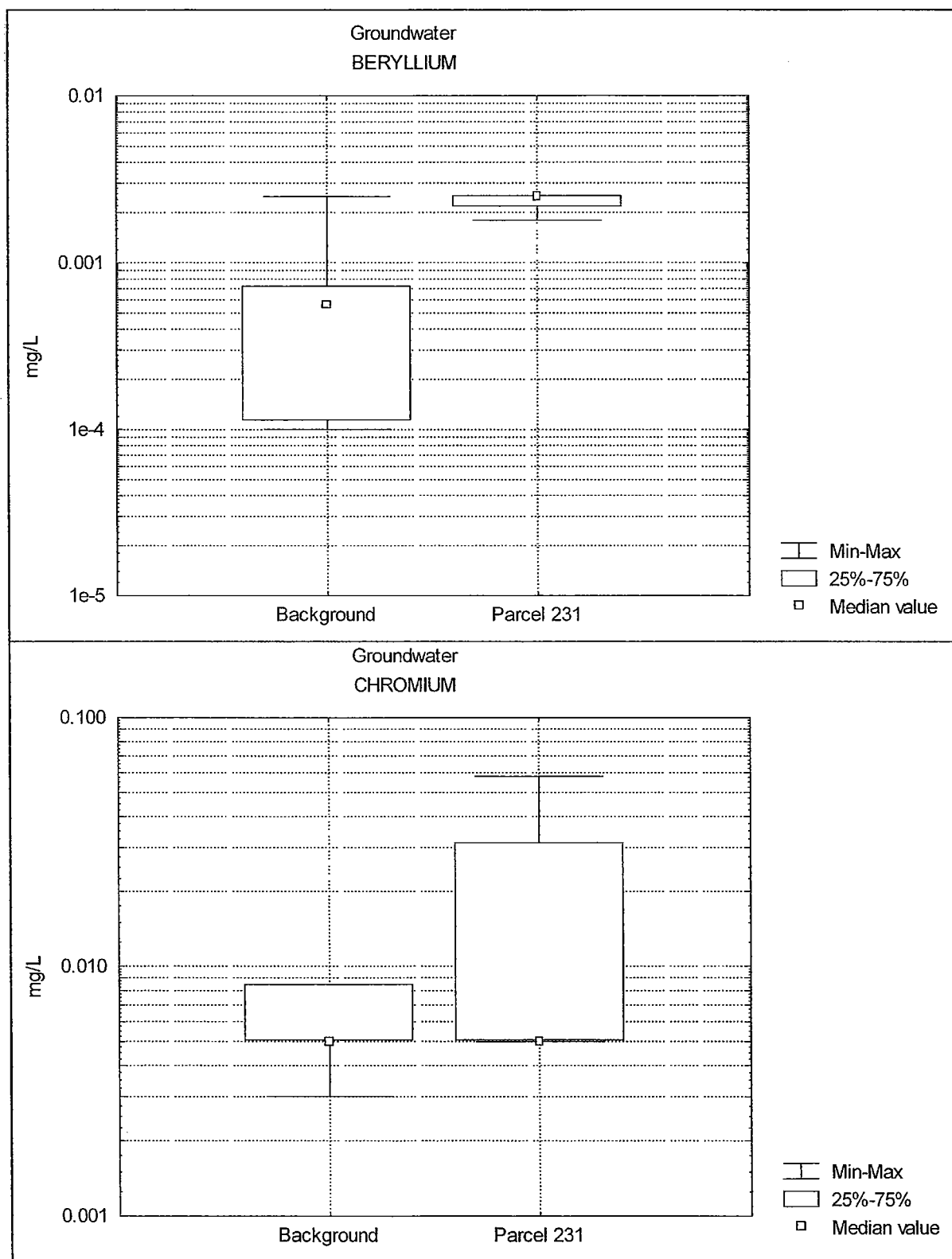


Figure 1-10

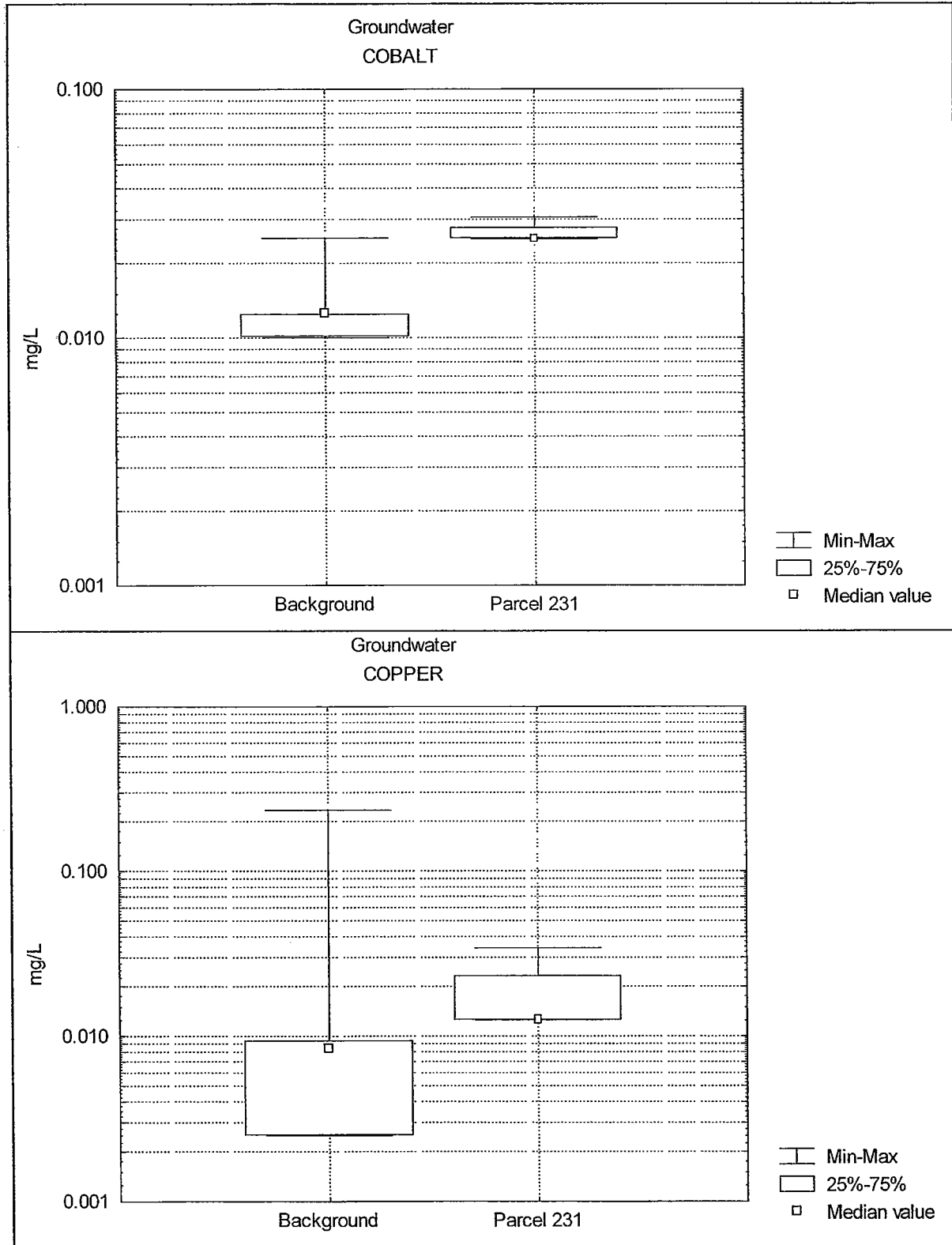




Figure 1-11

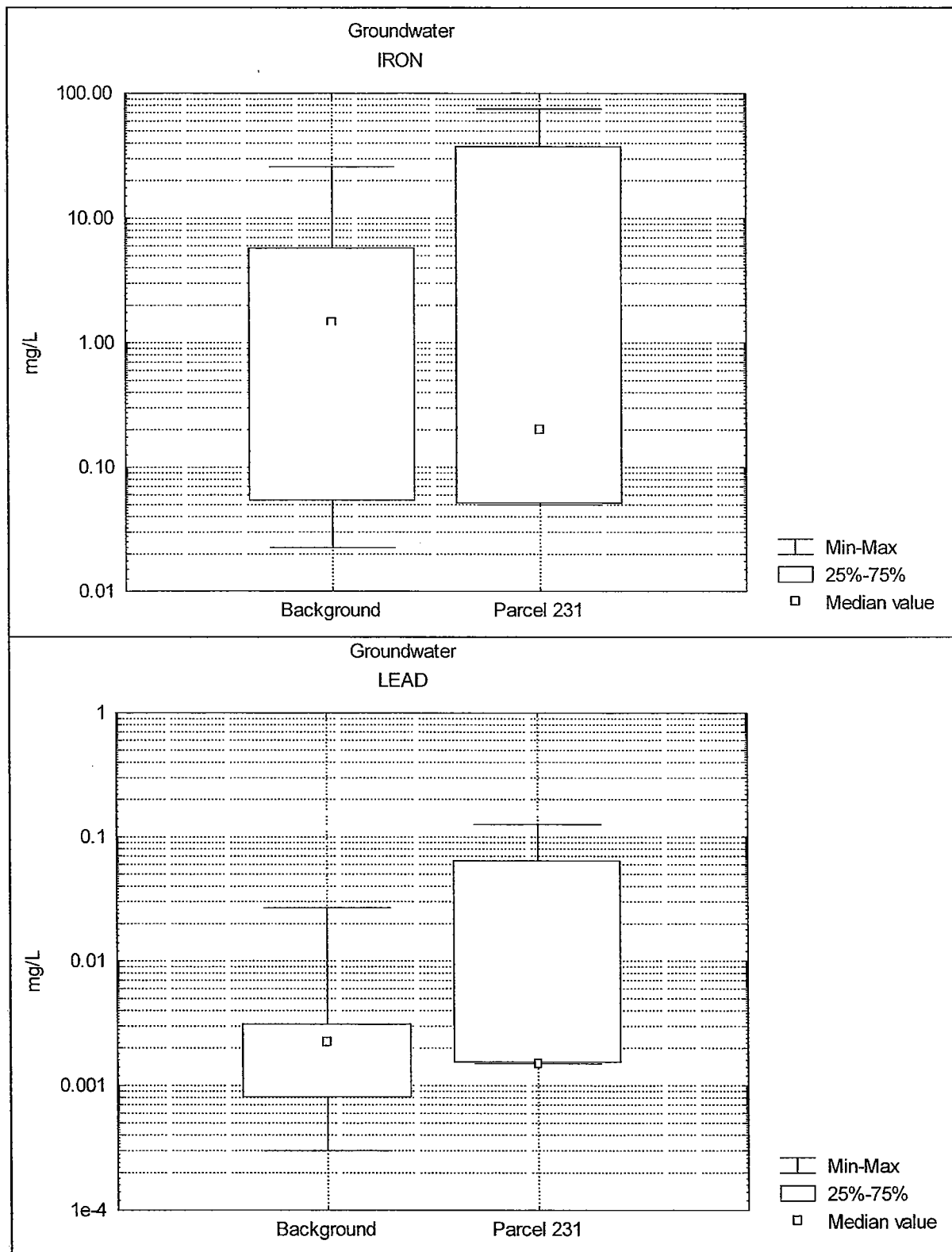


Figure 1-12

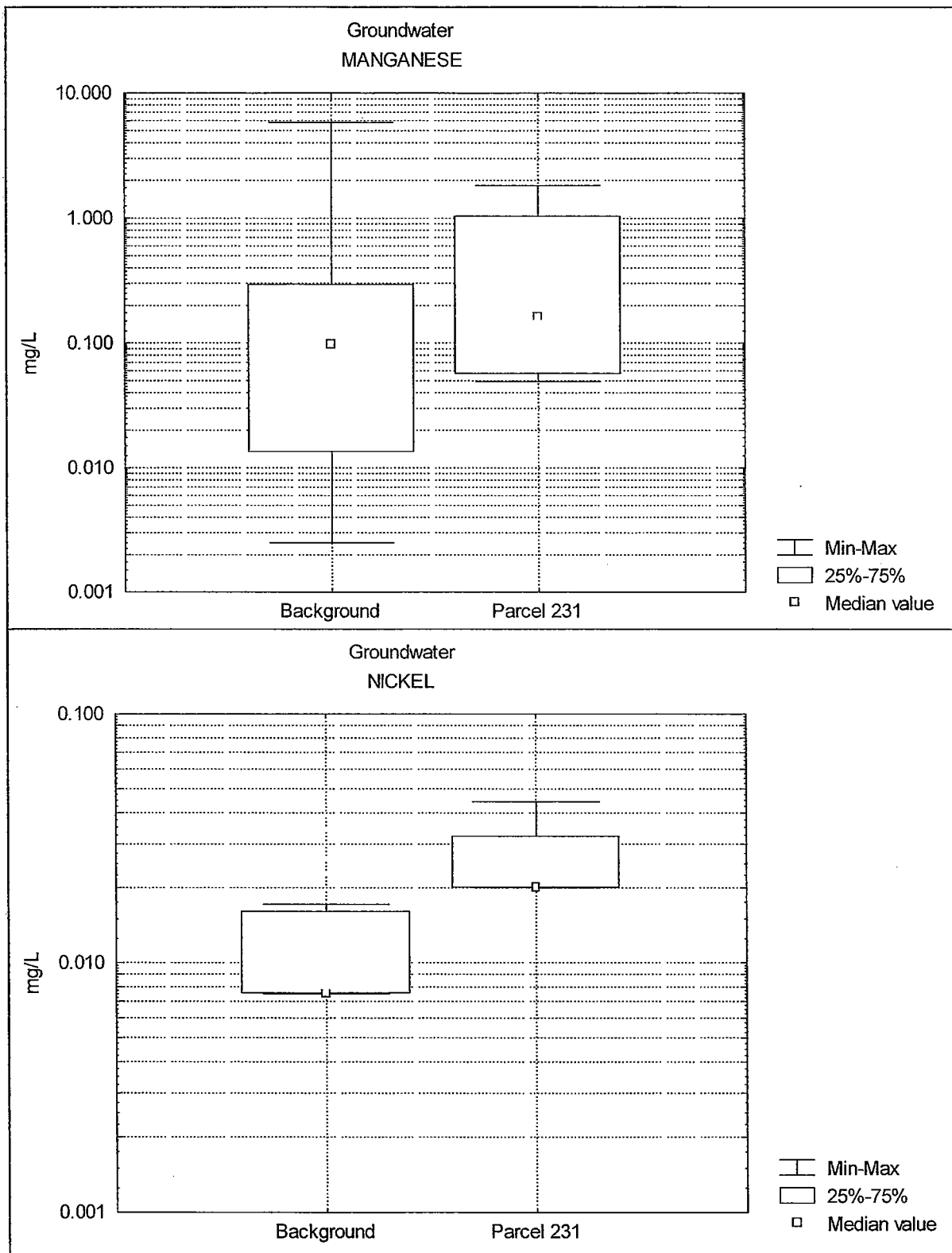
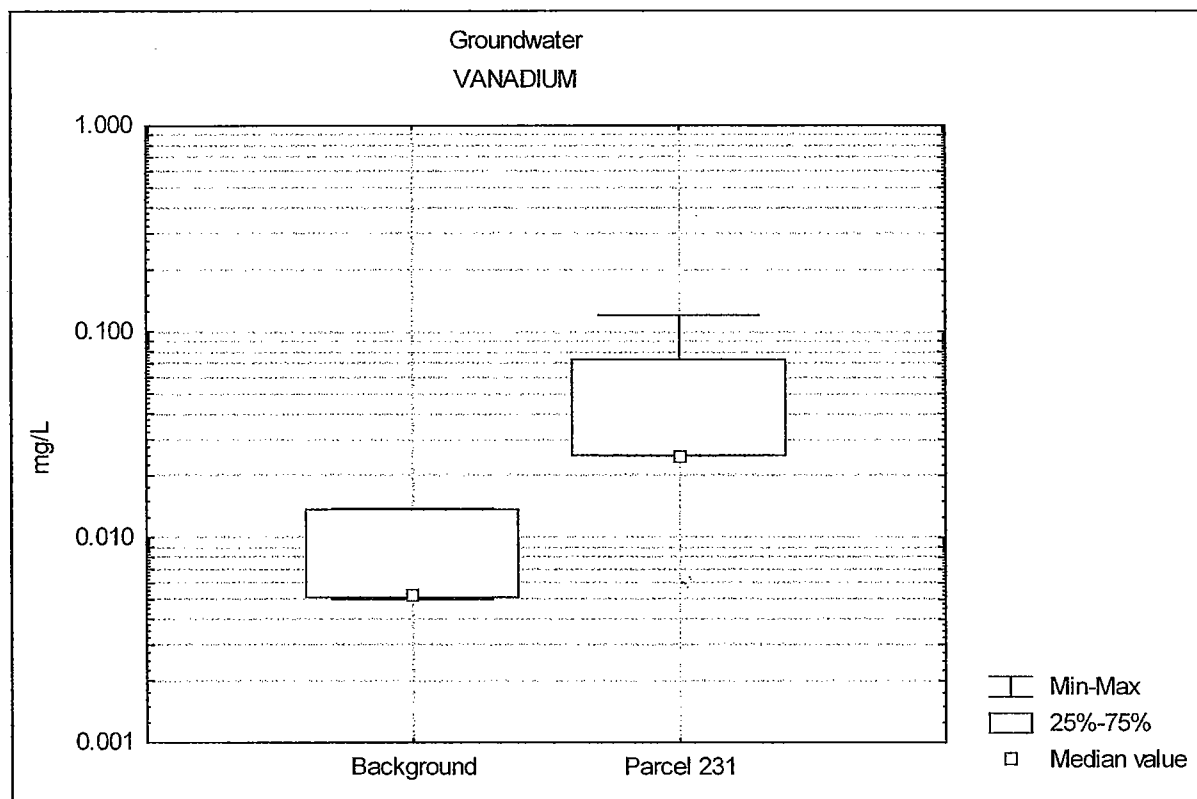


Figure 1-13



**GEOCHEMICAL  
(TIER 3)**

# **Geochemical Evaluation of Metals in Soil, Groundwater, and Surface Water at the Fill Area at Range 30, Parcel 231(7) Fort McClellan, Alabama**

## **1.0 Introduction**

This report provides the results of a geochemical evaluation of inorganic constituents in soil, groundwater, and surface water samples from the Fill Area at Range 30, Parcel 231(7), Fort McClellan, Calhoun County, Alabama. Four elements in soil, seven elements in groundwater, and one element in surface water failed statistical comparison to background. A geochemical evaluation was performed to determine if the elevated concentrations are naturally occurring or if they contain a component of contamination.

Site samples included in the evaluation consist of fourteen surface soil samples (obtained from depths of 0 to 0.3 foot below ground surface [bgs] and 0 to 1 foot bgs) collected from January through March 1999; eleven subsurface soil samples (various depths ranging from 4 to 12 feet bgs) collected in January and February 1999; four unfiltered groundwater samples collected in April 1999; and two unfiltered surface water samples collected in February and March 1999. All of the site samples were analyzed for the full suite of 23 target analyte list (TAL) metals. Installation-wide background data for TAL metals in soil, groundwater, and surface water are provided in the background study report (Science Applications International Corporation, 1998) and are used in the following evaluation.

## **2.0 Geochemical Evaluation Methodology**

Naturally occurring trace element concentrations in environmental media commonly exceed regulatory screening criteria. Trace element distributions in uncontaminated soil tend to have very large ranges (two to three orders of magnitude are not uncommon), and are highly right-skewed, resembling lognormal distributions. These trace elements are naturally associated with specific soil-forming minerals, and the preferential enrichment of a sample with these minerals will result in elevated trace element concentrations. It is thus important to be able to identify these naturally high concentrations and distinguish them from potential contamination.

If an analyte fails statistical comparison to background as described in the "Statistical Comparison of Site and Background Data for the Fill Area at Range 30, Parcel 231(7)," then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The importance of geochemical evaluations in distinguishing between site and

background data sets has been recognized in the industry (U.S. Environmental Protection Agency, 1995; Barclift, *et al.*, 2000; U.S. Navy, 2002; Myers and Thorbjornsen, 2004). When properly evaluated, geochemistry can provide mechanistic explanations for apparently high, yet naturally occurring, constituents. Anomalous samples that may represent contamination can also be readily distinguished from uncontaminated samples. This section describes the geochemical evaluation techniques that were employed in the site-to-background comparisons for Parcel 231(7). Additional supporting information on these techniques are provided in the installation-wide work plan (IT Corporation, 2002) and Shaw Environmental's technical memorandum dated May 1, 2003.

It should be noted that the geochemical evaluations rely in part on professional judgment and qualitative assessment is a necessary part of the process. Samples that plot off the linear trend on a correlation plot are certainly suspect, but because all uncertainty cannot be eliminated from the evaluation, such plots cannot be construed as definitive proof of contamination. However, anomalous samples should be flagged as suspect and their results used as a basis for further investigation, risk assessment, or remediation, as appropriate. The combination of statistical evaluations (Tiers 1 and 2) and geochemical evaluation (Tier 3) as presented in this appendix is effective in reducing the occurrences of decision errors relative to consideration of statistics or geochemistry alone.

## **2.1 Soil and Sediment**

The geochemical evaluation is based on the natural associations of trace elements with specific minerals in the soil or sediment matrix. As an example, arsenic in most uncontaminated oxic soils is almost exclusively associated with iron oxide minerals (Bowell, 1994; Schiff and Weisberg, 1997). (The term "iron oxide" is used here to include oxides, hydroxides, oxyhydroxides, and hydrous oxides of iron.) This association of arsenic with iron oxides is a result of the adsorptive behavior of this particular trace metal in an oxic soil environment. Arsenic is present in oxic soil pore fluid as negatively charged oxyanions ( $\text{HAsO}_4^{-2}$ ,  $\text{H}_2\text{AsO}_4^-$ ) (Brookins, 1988). These anions have strong affinities to adsorb on the surfaces of iron oxides, which maintain a strong positive surface charge (Electric Power Research Institute, 1986). If a soil sample has a high percentage of iron oxides, then it is expected to have a proportionally higher concentration of arsenic.

The absolute concentrations of arsenic and iron can vary by several orders of magnitude at a site, but the arsenic/iron ratios in the samples are usually quite constant as long as no contamination is present (Daskalakis and O'Connor, 1995). If a sample has some naturally occurring arsenic plus

additional arsenic from an herbicide or some other source, then it will have an anomalously high ratio relative to the other uncontaminated samples. These ratios thus serve as a powerful technique for identifying contaminated samples.

The evaluation includes the generation of plots in which detected arsenic concentrations in a set of samples are plotted on the y-axis, and the corresponding detected iron concentrations are plotted on the x-axis. The slope of a best-fit line through the samples is equal to the average As/Fe background ratio. If the samples with the highest arsenic concentrations plot on the same linear trend as the other samples, then it is most probable that the elevated concentrations are natural, and are caused by the preferential enrichment of iron oxides in those samples. If the site samples with elevated arsenic concentrations plot above the trend displayed by the uncontaminated samples, then there is evidence that those samples have an excess contribution of arsenic, and contamination may be indicated.

These trends may be linear or may have some curvature to them. The adsorption of a trace element on a mineral surface can usually be described by a linear isotherm over a limited range of concentrations, but a two-parameter curved fit (such as a Freundlich or Langmuir isotherm) can be more appropriate for some trace elements over a broader range of concentrations. The trace-versus-major element correlations are referred to as “linear trends” for convenience in this report, even though there may be some degree of curvature to the natural relationship.

Each trace element is associated with one or more minerals in the soil matrix. Vanadium and selenium, along with arsenic, form anionic species in solution and are associated with iron oxides, which maintain a positive surface charge. Divalent metals such as barium, cadmium, lead, and zinc tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. These trace elements would be evaluated against aluminum, which is a major component of clay minerals. Manganese oxides also have an affinity to adsorb divalent cations such as barium, cobalt, and lead (Kabata-Pendias, 2001). These trace elements would be evaluated against manganese.

## **2.2 Groundwater and Surface Water**

Elevated concentrations of inorganic constituents in groundwater and surface water samples may be due to naturally high dissolved concentrations, the presence of suspended particulates in the samples, reductive dissolution, or contamination resulting from site activities. This section discusses the major geochemical processes considered during the evaluation of groundwater and surface water analytical data.

**Effects of Suspended Particulates.** The presence of trace elements adsorbed on suspended particulates can greatly increase trace element concentrations as reported by an analytical laboratory. These adsorbed trace elements are not in true solution, and can be removed by settling or filtration. The same concepts involved in the evaluation of soil and sediment data also apply to groundwater and surface water data: samples containing trace elements adsorbed on suspended clay particulates should show a positive correlation with aluminum concentrations, and samples containing trace elements adsorbed on suspended iron oxides should show a positive correlation with iron concentrations. These correlations are evaluated by generating x-y plots of the concentrations of an elevated trace metal versus aluminum or iron (depending on the trace element).

The most common suspended particulates in groundwater samples are clay minerals; hydrous aluminum oxides ( $\text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ ) and hydroxides [ $\text{Al}(\text{OH})_3$ ]; and iron oxide ( $\text{Fe}_2\text{O}_3$ ), iron hydroxide [ $\text{Fe}(\text{OH})_3$ ], and iron oxyhydroxide ( $\text{FeO} \cdot \text{OH}$ ) minerals, collectively referred to as “iron oxides.” All clay minerals contain aluminum and have low solubilities over a neutral pH range of 6 to 8. Measured concentrations of aluminum in excess of ~1 milligram per liter (mg/L) indicate the presence of suspended clay minerals (Hem, 1985; Stumm and Morgan, 1996), with higher aluminum concentrations being a qualitative indicator of the mass of suspended clay minerals. Iron also has a very low solubility under neutral pH and moderate to oxidizing redox conditions, so that measured iron concentrations in excess of ~1 mg/L under these conditions indicate the presence of suspended iron oxides (Hem, 1985).

The presence of suspended clay or iron oxides in groundwater samples has particular importance in the interpretation of trace element concentrations. Most clay particles maintain a negative surface charge under neutral pH conditions, and have a strong tendency to adsorb positively charged (cationic) aqueous species. Iron oxides display the opposite behavior; they maintain a positive surface charge under neutral pH conditions, and have a strong tendency to adsorb negatively charged (anionic) aqueous species.

Barium, lead, and zinc are usually present in groundwater as divalent cations and thus tend to concentrate on clay surfaces (Electric Power Research Institute, 1984; Brookins, 1988). Arsenic, selenium, and vanadium are usually present under oxidizing conditions as oxyanions, and thus tend to concentrate on iron oxide surfaces (Bowell, 1994; Hem, 1985; Pourbaix, 1974; Brookins, 1988).



Chromium can be present in groundwater as a mixture of aqueous species with different charges, depending on pH (Electric Power Research Institute, 1984). The positive, neutral, and negative charges on these species result in the distribution of chromium on several different types of sorptive surfaces, including clay and iron oxide minerals.

As an example, the concentrations of zinc (y-axis) would be plotted against aluminum (x-axis). If all of the samples display a common linear trend, then it is most likely that the zinc concentrations are due to the presence of suspended clay minerals in the samples. The slope of a best-fit line through the points is equal to the average Zn/Al ratio. If some samples plot above the linear trend established by the other samples, then those samples have an anomalously high Zn/Al ratio, and most likely contain excess zinc that cannot be explained by these natural processes.

These trends may be linear or may have some curvature to them. The adsorption of a trace element on a mineral surface can usually be described by a linear isotherm over a limited range of concentrations, but a two-parameter curved fit (such as a Freundlich or Langmuir isotherm) can be more appropriate for some trace elements over a broader range of concentrations. The trace-versus-major element correlations are referred to as “linear trends” for convenience in this report, even though there may be some degree of curvature to the natural relationship.

Alternative techniques for assessing the effects of suspended particulates on trace element concentrations are the evaluation of correlations of trace element concentrations versus turbidity, and comparison of analyses of filtered versus unfiltered splits of samples. Turbidity measurements are qualitative, and do not distinguish between suspended clay minerals, iron oxides, and natural organic material, so this approach lacks the resolution provided by trace element versus aluminum or trace element versus iron correlations.

If the concentrations of trace elements in unfiltered samples are correlated with aluminum or iron, then they are most likely adsorbed to the surfaces of suspended particulates. If these correlations are linear, then the elevated concentrations are most likely natural.

***Effects of Reductive Dissolution.*** Iron and manganese oxides concentrate several trace elements such as arsenic, selenium, and vanadium on mineral surfaces, as discussed above. In soils and sedimentary aquifers, these elements are almost exclusively associated with iron and manganese oxide minerals and grain coatings, as long as the redox conditions are moderate to oxidizing.

The release of organic contaminants such as fuels or chlorinated solvents can establish local reducing environments caused by anaerobic microbial degradation of the organic compounds. The establishment of local reducing conditions can drive the dissolution of iron and manganese oxides, which become soluble as the redox potential drops below a threshold value. Dissolution of these oxide minerals can mobilize the trace elements that were adsorbed on the oxide surfaces, which is a process termed “reductive dissolution.” Several investigations have documented the mobilization of arsenic, selenium, and other trace elements under locally reducing redox conditions (Sullivan and Aller, 1996; Nickson, *et al.*, 2000; Belzile, *et al.*, 2000).

Evidence for reductive dissolution would be a correlation between elevated trace elements (arsenic, selenium, and vanadium in particular) versus lower redox conditions. Low redox conditions can be identified by local depressions in oxidation-reduction potential (ORP) or dissolved oxygen (DO) measurements, or the presence of reducing gases such as hydrogen, methane, ethane, or ethene. Anaerobic microbes can also reduce sulfate to sulfide and nitrate to ammonia, resulting in local depressions in sulfate and nitrate concentrations, and local detections of sulfide and ammonia. In areas impacted by chlorinated solvents, additional evidence for the establishment of anaerobic reducing conditions is the presence of *cis*-1,2-dichloroethene and/or vinyl chloride, which are reductive dechlorination products resulting from the microbial degradation of trichloroethene or tetrachloroethene under anaerobic conditions.

### **3.0 Results of the Geochemical Evaluation of Multiple Elements in Soil**

This section presents the results of the geochemical evaluation of copper, lead, mercury, and selenium in soil samples from Parcel 231(7). Correlation plots are provided in Attachment 1.

#### **Copper**

Copper in soil has an affinity to adsorb on the surfaces of minerals such as clays and iron oxides (Kabata-Pendias, 2001). Iron is the most abundant element analyzed in the Parcel 231(7) soil samples, with a mean concentration of 20,308 mg/kg (2 weight percent). The site soil boring logs note that yellowish red, dark red, reddish brown, or dark brown clay or silt with clay; and yellowish red to dark red sand with some clay are the predominant soil types in many of the sampled intervals. The iron in the samples is dominantly present as iron oxides, which are highly pigmented and impart the red color to the site soils. Iron oxides are common soil-forming minerals, and occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003). Aluminum is the second most abundant element analyzed in the site sediment samples (mean concentration of 6,980 mg/kg; approximately 0.7 weight percent), and is a primary component of minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and can adsorb on iron oxide surfaces (Cornell

and Schwertmann, 2003). Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes.

A plot of aluminum versus iron concentrations can be used as a qualitative indicator of the relative abundance of clay and iron oxide minerals in site soil (Figure 1). The site and background samples form a common, generally linear trend with a positive slope. The site samples with the highest iron concentrations also have proportionally higher aluminum, and lie on the background trend. The site samples have Al/Fe ratios that are similar to those of the background samples, which indicates a natural source for these two elements in the site samples. The samples that plot on the upper end of the trend in Figure 1 are naturally enriched in clays and iron oxides relative to the other samples, and thus they are expected to contain proportionally higher concentrations of specific trace elements, such as copper, which have an affinity to adsorb on these mineral surfaces.

A plot of copper versus iron is provided in Figure 2. Most of the background samples form a linear trend with a positive slope, and the site samples lie on this trend. The site samples with high copper concentrations also have proportionally higher iron content. These observations indicate that copper in the site samples is associated with iron oxides at ratios consistent with those of the background samples, and is natural.

#### Conclusion

Copper detected in the site soil samples is naturally occurring.

#### **Lead**

As discussed in Section 2.1, manganese oxides have an affinity to adsorb divalent cations such as barium, cobalt, and lead (Kabata-Pendias, 2001). If a soil sample contains a high proportion of manganese oxides, then it is expected to contain high concentrations of manganese and associated trace elements. A plot of lead versus manganese is provided in Figure 3. The site and background samples form a common linear trend with a positive slope. The site samples with the highest lead concentrations also exhibit Pb/Mn ratios that are similar to those of the background samples, and lie on the linear trend. These observations indicate that lead in the site samples is associated with manganese oxides at ratios consistent with those of the background samples, and is natural.

#### Conclusion

Lead detected in the site soil samples is naturally occurring.

#### **Mercury**

Mercury concentrations in soil are commonly controlled through organic complex formation (Kabata-Pendias, 2001), so weak correlations between mercury and iron or mercury and aluminum are often observed, even in uncontaminated soil samples. The background samples form a weak linear trend with a positive slope in a plot of mercury versus iron, and all of the site samples lie on this trend (Figure 4). This indicates that mercury in the site samples is associated with iron oxides at ratios consistent with those of the background samples, and is natural.

#### Conclusion

Mercury detected in the site soil samples is naturally occurring.

## **Selenium**

As discussed in Section 2.1, selenium has a strong affinity to adsorb on iron oxides in oxic soils, so a positive correlation between selenium and iron is expected for uncontaminated soil samples under those conditions. Comparison to background is hindered because of the high percentage of nondetects in the background data set. A plot of selenium versus iron is provided in Figure 5. The site samples with detectable selenium form a generally linear trend with a positive slope, and the two background samples with detectable selenium lie on and slightly above this trend. The site samples with the highest selenium concentrations also exhibit high iron concentrations and lie on the linear trend, which indicates that these samples are preferentially enriched in iron oxides and associated trace elements. Selenium in these samples is natural.

## **Conclusion**

Selenium detected in the site soil samples is naturally occurring.

## ***4.0 Results of the Geochemical Evaluation of Multiple Elements in Groundwater***

This section presents the results of the geochemical evaluation of aluminum, chromium, cobalt, iron, lead, nickel, and vanadium in the four unfiltered groundwater samples from Parcel 231(7). Correlation plots are provided in Attachment 1.

Field-measured pH readings are available for three of the four site groundwater samples, and they range from 4.86 to 4.93 standard units, with a median of 4.91. These values indicate slightly acidic conditions at the sample locations. Field-measured DO readings range from 4 to 6.5 mg/L, with a median of 5.9 mg/L and mean of 5.6 mg/L, and ORP readings range from +280 to +385 millivolts (mV), with a median of +304 mV and mean of +318 mV. These values suggest oxidizing redox conditions at all of the sample locations. Turbidity measurements range from 1.1 to 1000 nephelometric turbidity units (NTU), with a median of 5.6 NTU. Although three of the samples did not contain a significant mass of suspended particulates (turbidity of 9.1 NTU or lower), site sample KT3001 (from sample location PPMP-231-GP01) did exhibit elevated turbidity (1000 NTU). It should be noted that field readings are not available for the background samples.

## **Aluminum**

Aluminum was detected in all four unfiltered groundwater samples (two of these concentrations have “B” validation qualifiers, but they are treated as estimated detected concentrations for the purposes of this geochemical evaluation). As discussed previously, aluminum concentrations in excess of approximately 1 mg/L in neutral pH groundwater indicate the presence of suspended clays. Aluminum will be present in solution at a pH below about 4.0, but the Parcel 231(7) pH

readings are higher than this (see the discussion of field readings, above) and so the aluminum in the site samples is expected to be present in particulate form.

Iron concentrations in excess of approximately 1 mg/L in neutral-pH, moderate to oxidizing groundwater conditions indicate the presence of suspended iron oxides. A plot of aluminum versus iron can be used as a qualitative indicator of the amount of suspended particulates in the groundwater samples (Figure 6). The site samples and the majority of background samples form a linear trend with a positive slope, indicating that both elements are present in particulate form in these samples. Site sample KT3001 (collected from sample location PPMP-231-GP01) contains the highest aluminum concentration of both data sets (29.6 mg/L) but it also contains proportionally higher iron and elevated turbidity (1000 NTU), and it lies on the linear trend established by the other samples in the plot. Elevated aluminum in this sample is due to the presence of suspended particulates such as clays, and is natural.

It is worth noting that suspended clays and iron oxides adsorb specific trace elements (as discussed in Section 2.2), so samples that plot on the upper end of the trend in Figure 6 – including site sample KT3001 – are expected to contain proportionally higher concentrations of associated trace elements.

#### Conclusion

Aluminum detected in the site groundwater samples is naturally occurring.

#### **Chromium**

Chromium was detected in only one of the four unfiltered groundwater samples, at an estimated concentration of 0.058 mg/L. Comparison to background is precluded by the lack of detectable chromium in the background samples. As noted in Section 2.2, chromium can be present in groundwater as a mixture of aqueous species with different charges, and thus it can adsorb on different surfaces, including clay and iron oxide minerals. Plots of chromium versus aluminum and chromium versus iron cannot be constructed due to the lack of detectable chromium in three of the site samples. However, the single site sample with detectable chromium (KT3001) contains the highest aluminum concentrations of both data sets (29.6 mg/L), proportionally higher iron (74.8 mg/L; Figure 6), and elevated turbidity (1000 NTU). This indicates that sample KT3001 contains a significant mass of suspended particulates such as clays and iron oxides, and that the elevated chromium in this sample is due to the presence of these particulates.

#### Conclusion

Chromium detected in the site groundwater samples is naturally occurring.

#### **Cobalt**

Cobalt was detected in two of the four unfiltered groundwater samples. Under oxidizing groundwater conditions, cobalt concentrations are commonly controlled by adsorption on iron oxides and manganese oxides (Hem, 1985). Field readings for the site samples indicate oxidizing redox conditions, and the site Al/Fe ratios indicate the presence of suspended particulates such as clays and iron oxides. Given these observations, cobalt concentrations in site

groundwater are expected to be at least partly controlled by adsorption on suspended particulates such as iron oxides.

A plot of cobalt versus iron is provided in Figure 7. The background samples do not exhibit a positive correlation. However, the site samples exhibit a positive correlation; sample KT3001 contains the highest cobalt concentration of the site and background samples (0.0306 J mg/L), but it also contains the highest iron (74.8 mg/L) and elevated turbidity (1000 NTU). This suggests that the elevated cobalt is due to the presence of suspended particulates such as iron oxides, and that the cobalt is natural.

### Conclusion

Cobalt detected in the site groundwater samples is naturally occurring.

### **Iron**

Iron was detected in all four unfiltered groundwater samples (two of these concentrations have “B” validation qualifiers, but they are treated as estimated detected concentrations for the purposes of this geochemical evaluation). As discussed in Section 2.2, iron concentrations above about 1 mg/L in neutral-pH, moderate to oxidizing redox conditions reflect the presence of suspended iron oxides. Iron is a redox-sensitive element, and its dissolved concentrations will increase under reducing conditions. Reducing conditions can be natural, or they can be induced by the anaerobic microbial degradation of chlorinated solvents and fuels (see Section 2.2). However, field readings for the site samples indicate oxidizing conditions at all four locations during the sampling event, and the only VOCs (carbon disulfide and chloroform) detected in the site samples are present at estimated concentrations below the reporting limit. The available pH readings indicate that the groundwater was slightly acidic at the time of sample collection. Under these conditions, iron is expected to be present primarily as suspended particulates, although some portion of the detected concentrations may be in solution, depending on the sample.

As discussed in the Aluminum evaluation (above), aluminum concentrations in excess of approximately 1 mg/L in neutral pH groundwater indicate the presence of suspended clays. A positive correlation is expected between aluminum and iron concentrations in neutral-pH, moderate to oxidizing groundwater. A plot of detected aluminum concentrations versus detected iron concentrations can be used as a qualitative indicator of the amount of suspended particulates in the samples (Figure 6). The four site samples and the majority of background samples form a linear trend with a positive slope, indicating that both elements are present in particulate form in these samples. Site sample KT3001 (collected from sample location PPMP-231-GP01) contains the highest iron concentration of both data sets (74.8 mg/L) but it also contains proportionally higher aluminum and elevated turbidity (1000 NTU), and it lies on the linear trend established by the other samples in Figure 6. Elevated iron in this sample is due to the presence of suspended particulates such as iron oxides, and is natural.

It should be noted that suspended clays and iron oxides adsorb specific trace elements (as discussed in Section 2.2), so samples that plot on the upper end of the trend in Figure 6 – including site sample KT3001 – are expected to contain proportionally higher concentrations of associated trace elements.

### Conclusion

Iron detected in the site groundwater samples is naturally occurring.

### **Lead**

Lead was detected in only one of the four unfiltered groundwater samples, at a concentration of 0.126 mg/L. As discussed in Section 2.2, under natural conditions lead has an affinity to adsorb on suspended clays, which contain aluminum as a primary constituent. A positive correlation between lead and aluminum concentrations is thus expected for uncontaminated samples. The site samples and most of the background samples form a linear trend with a positive slope in a plot of lead versus aluminum (Figure 8). Site sample KT3001 contains higher lead than the background samples, but it also contains proportionally higher aluminum (29.6 mg/L) and elevated turbidity (1000 NTU), and lies on the linear background trend. Lead in sample KT3001 is associated with suspended clays at a ratio consistent with those of the background samples, and is natural.

### Conclusion

Lead detected in the site groundwater samples is naturally occurring.

### **Nickel**

Nickel was detected in only one of the four unfiltered groundwater samples, at a concentration of 0.0444 mg/L. Comparison to background is precluded by the lack of detectable nickel in the background samples. Nickel is commonly present as the divalent cation  $\text{Ni}^{2+}$  when redox conditions are moderate to oxidizing and pH values are below about 9 standard units (Brookins, 1988). This species has an affinity to adsorb on the surfaces of iron oxides such as hydrous ferric oxide (Deutsch, 1997), and a positive correlation between nickel and iron concentrations is commonly observed under these conditions. Field-measured pH values are all below 9 and redox conditions at the site are oxidizing, so nickel concentrations in site groundwater are expected to be controlled to some degree by adsorption on iron oxides. A plot of nickel versus iron cannot be constructed due to the lack of detectable nickel in three of the site samples. However, the single site sample with detectable nickel (KT3001) contains the highest iron concentration of both site and background data sets (74.8 mg/L), proportionally higher aluminum (29.6 mg/L; Figure 6), and elevated turbidity (1000 NTU). This indicates that sample KT3001 contains a significant mass of suspended particulates such as clays and iron oxides, and that the elevated nickel in this sample is due to the presence of these particulates.

### Conclusion

Nickel detected in the site groundwater samples is naturally occurring.

### **Vanadium**

Vanadium was detected in only one of the four unfiltered groundwater samples, at a concentration of 0.12 mg/L. As discussed in Section 2.2, vanadium is usually present under oxidizing conditions as an oxyanion and tends to concentrate on iron oxide surfaces, which maintain a positive surface charge. A positive correlation between vanadium and iron concentrations is expected for uncontaminated samples under those conditions. Redox conditions at the site are oxidizing, so vanadium concentrations in site groundwater are expected

to be controlled primarily by adsorption on iron oxides. A plot of vanadium versus iron is provided in Figure 9. The two background samples with detectable vanadium do not exhibit a positive correlation. However, the single site sample with detectable vanadium (KT3001) contains the highest iron concentration of both site and background data sets (74.8 mg/L), proportionally higher aluminum (29.6 mg/L; Figure 6), and elevated turbidity (1000 NTU). These observations indicate that the elevated vanadium in sample KT3001 is due to the presence of suspended particulates (such as iron oxides), and is natural.

#### Conclusion

Vanadium detected in the site groundwater samples is naturally occurring.

### **5.0 Results of the Geochemical Evaluation of Calcium in Surface Water**

This section presents the results of the geochemical evaluation of calcium in the two unfiltered surface water samples from Parcel 231(7). Correlation plots are provided in Attachment 1.

Field-measured pH readings for surface water samples KT2001 (PPMP-231-SEP01) and KT2004 (PPMP-231-SW/SD01) are 7.85 and 6.05 standard units, respectively, indicating neutral-pH conditions at the time of sample collection. DO readings are 10.4 mg/L and 6.4 mg/L, and the ORP reading for sample KT2001 is +224 mV (an ORP measurement is not available for sample KT2004). These values suggest oxidizing redox conditions at both sample locations. Turbidity measurements are 1.2 NTU and 33 NTU, indicating that the samples did not contain a significant mass of suspended particulates. It should be noted that field readings are not available for the background samples.

#### **Calcium**

Calcium was detected in both unfiltered surface water samples, at concentrations of 0.247 J mg/L and 62.5 mg/L. Calcium and magnesium are major dissolved constituents in surface waters, and their concentrations often covary in uncontaminated samples. A plot of calcium versus magnesium is provided in Figure 10. Most of the background samples form a strong linear trend with a positive slope. Sample KT2004 contains the lower calcium concentration of the two site samples, and it also contains the lower magnesium concentration and lies on the bottom left portion of the linear background trend. Sample KT2001 contains the higher calcium concentration of the two site samples and the second-highest calcium of the combined data sets, but it also contains proportionally higher magnesium and lies on the linear background trend. These observations indicate a natural source for calcium in the site samples.

#### Conclusion

Calcium detected in the site surface water samples is naturally occurring.



## 6.0 Summary

This section summarizes the results of the geochemical evaluations of selected elements in soil, groundwater, and surface water samples from Parcel 231(7).

**Soil.** Geochemical evaluation indicates that all detected concentrations of copper, lead, mercury, selenium in the site surface and subsurface soil samples are naturally occurring.

**Groundwater.** Geochemical evaluation indicates that the detected concentrations of aluminum, chromium, cobalt, iron, lead, nickel, and vanadium in the site groundwater samples are naturally occurring.

**Surface Water.** Geochemical evaluation indicates that detected concentrations of calcium in the site surface water samples are naturally occurring.

## 7.0 References

- Barclift, D., J. Heath, and A. Drucker, 2000, "Focus on Environmental Background Data Analysis," *Soil Sediment & Groundwater*, August/September, pp. 10-17.
- Belzile, N., Y. W. Chen, and R. Xu, 2000, "Early diagenetic behavior of selenium in freshwater sediments," *Applied Geochemistry*, Vol. 15, No. 10, pp. 1439-1454.
- Bowell, R. J., 1994, "Sorption of arsenic by iron oxides and oxyhydroxides in soils," *Applied Geochemistry*, Vol. 9, No. 3, pp. 279-286.
- Brookins, D. G., 1988, *Eh-pH Diagrams for Geochemistry*, Springer-Verlag.
- Cornell, R. M. and U. Schwertmann, 2003, *The Iron Oxides: Structure, Properties, Reactions, Occurrences and Uses*, Second Edition, Wiley-VCH, Weinheim.
- Daskalakis, K. D. and T. P. O'Connor, 1995, "Normalization and Elemental Sediment Contamination in the Coastal United States," *Environmental Science & Technology*, Vol. 29, No. 2, pp. 470-477.
- Deutsch, W. J., 1997, *Groundwater Geochemistry: Fundamentals and Applications to Contamination*, Lewis Publishers, Boca Raton.
- Drever, J. I., 1997, *The Geochemistry of Natural Waters*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.
- Electric Power Research Institute, 1984, *Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration, Volume 1: A Critical Review*, EPRI EA-3356, Palo Alto, California.

Electric Power Research Institute, 1986, *Speciation of Selenium and Arsenic in Natural Waters and Sediments, Volume 2: Arsenic Speciation*, EPRI EA-4641, Palo Alto, California.

Hem, J. D., 1985, *Study and Interpretation of the Chemical Characteristics of Natural Water*, U. S. Geological Survey, Water Supply Paper 2254, 3<sup>rd</sup> Edition.

IT Corporation, 2002, *Draft Installation-Wide Work Plan, Fort McClellan, Calhoun County, Alabama, Revision 2*, Prepared for the U.S. Army Corps of Engineers, Mobile District, February.

Kabata-Pendias, A., 2001, *Trace Elements in Soils and Plants*, Third Edition, CRC Press.

Myers, J. and K. Thorbjornsen, 2004, "Identifying Metals Contamination in Soil: A Geochemical Approach," *Soil & Sediment Contamination: an International Journal*, Vol. 13, No. 1, pp. 1-16.

Nickson, R. T., J. M. McArthur, P. Ravenscroft, W. G. Burgess, and K. M. Ahmed, 2000, "Mechanism of arsenic release to groundwater, Bangladesh and West Bengal," *Applied Geochemistry*, Vol. 15, pp. 403-413.

Pourbaix, 1974, *Atlas of Electrochemical Equilibria in Solutions*, National Association of Corrosion Engineers, Houston, Texas.

Science Applications International Corporation, 1998, *Final Background Metals Survey Report, Fort McClellan, Anniston, Alabama*, July.

Schiff, K. and S. B. Weisberg, 1997, "Iron as a Reference Element for Determining Trace Metal Enrichment in California Coastal Shelf Sediments," in: S. Weisberg, C. Francisco, and D. Hallock, (eds.), *Southern California Coastal Water Research Project Annual Report 1995-96*, pp. 68-78.

Stumm, W. and J. Morgan, 1996, *Aquatic Chemistry*, Third Edition, Wiley-Interscience, New York.

Sullivan, K. A. and R. C. Aller, 1996, "Diagenetic cycling of arsenic in Amazon shelf sediments," *Geochimica et Cosmochimica Acta*, Vol. 60, No. 9, pp. 1465-1477.

U.S. Environmental Protection Agency, 1995, *Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites*, Office of Research and Development, EPA/540/S-96/500, December.

U.S. Navy, 2002, *Guidance for Environmental Background Analysis, Volume 1: Soil*, NFESC User's Guide UG-2049-ENV, Naval Facilities Engineering Command, Washington, D.C., April.

## **ATTACHMENT 1**

